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A PENGUIN SPECIAL

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LIFE IN THE TWENTY-FIRST CENTURY

EDITED BY M. VASSILIEV AND
S. GOUSCHEV

LIFE IN THE TWENTY-FIRST CENTURY

EDITED BY

M. Vassiliev and S. Gouschev

AND TRANSLATED BY

H. E. Crowcroft A.M.I.E.E. *and*

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Introduction

Clearly, the principal characteristic of the second half of the present century, and one which will have an increasing effect on the life of everyone, is likely to be the contest between East and West in all the various fields of technology.

Just how massive and far-reaching this contest is, and how intensive the specialized research behind it, has hitherto been difficult for the layman to grasp fully. Certainly, while descriptions of Western scientific achievements and aspirations have poured from the presses, little or nothing has emerged about Russia's plans. It has been left to Russian sputniks and moon probes suddenly to astound the Western world.

This remarkable book does much to lift the veil of mystery surrounding the subject. Twenty-nine distinguished Russian scientists were interviewed about their present research and asked for their carefully considered predictions on likely developments during the next fifty years. The picture of life that emerges is in many respects breath-taking, but it carries the unassailable authority of acknowledged experts who have staked their reputations on its accuracy and probability.

CHAPTER I

Learn to Dream

OUR first visit was to the study of Alexander Nikolaievich Nessmayanov. On a huge desk stood a bronze Atlas bearing on his shoulders a gleaming globe. Portraits of Russian scientists hung on the walls. In one corner a wooden bust of Lenin, smiling, the work of the well-known sculptor S. T. Konienkov . . .

We told him of our plan.

'Your idea appeals to me,' said the professor, after a brief pause. He was calm and relaxed. 'To give a glimpse of the next century, to try and foresee what will be the practical outcome of the ideas which are being born today. All this in fact is propaganda for the most interesting achievements of modern science and technology, an important and useful enterprise. It is a scientific dream, a kind of prognostication of the development of science over a long period, and could give noteworthy results. We do not always care to dream, nor are we always capable of dreaming, but it is essential to do so. Without dreams prospects do not exist, without dreams man, the scientist included, is inevitably halted in his progress. Creation is not consistent with kicking one's heels.

'I should like to compare science in its development with a tall tree with many branches and its roots deeply embedded in the soil. The natural requisite of science is maximum prolificity. Science in our socialist society has one single aim: to serve man to the best of its ability, to satisfy his material needs, and, what is even more important, his spiritual needs and necessities. But however rich the vital sources for its growth which the tree draws from the soil, the plant cannot grow or give fruit without the sun. For science and for the scientist this sun is the high inspiring idea which shines and warms the scientist and gives him the strength to create. The higher the development of technique, the more deeply the tree plunges its roots into production and practice. And is it not so, that as the tree's roots grow, the trunk does likewise, and its branches rise ever higher towards the sun?

'Basing itself on the imposing present-day successes in applied technology, science should keep as its aim the tackling of ever more arduous problems, the realization of which will be an appreciable contribution in the building of a communist society, the eternal dream of the human race.

'An urge to look constantly ahead distinguishes the *avant garde* revolutionaries of our country. Remember how Radischev, who was both a brilliant man and a good man, dreamed of a better future and of the new Russia. "I dream through a whole century," he said.

'Remember Chernischevsky, who tried to represent in his works not only human relationships in a new socialist society, still unknown in his age, but also tried to imagine the customs of the men of the new world, to see their dwellings of aluminium, and to examine the machines which could alleviate the toil of the free man.

'Without such a capacity for imagining the future, at least in general outline, people would not have been able to solve complicated problems of a scientific, economic, or political order. One must cultivate this capacity in oneself – one must learn to dream, and so coordinate the work of today with the problems of tomorrow.

'The present-day level of science and the dynamism of its constant development not only allow us to make with confidence the most optimistic forecasts for the future, but often surpass the winged fantasies of certain writers – for indeed, do not many of the problems solved by our scientists border on the fantastic?

'The year 1957 holds a particular place in the history of the human race. In that year an event took place the importance of which we contemporaries have hardly understood because of its grandeur. It may perhaps be compared with the discovery of fire, the first use of iron, the invention of the steam engine, the discovery of atomic energy. I am referring, of course, to the triumph of Soviet science and technology with the launching of the first sputniks, the first artificial satellites. Heavenly bodies, created by human hands, have been launched into space, and these have already rewarded science with visible and tangible results. The first space laboratories have transmitted by radio secrets of the ionosphere and of cosmic rays; they have also provided information as to the reactions of a living creature when exposed to interplanetary space.

'A revolution has begun in mental work which may be compared with the revolution which took place in the field of production when manual labour was replaced by the machine. I am referring to the creation of electronic calculating machines capable of working out in a few minutes mathematical calculations which would need months and years of intensive work by a team of mathematicians. Such machines make possible the full automation of the most complex plant or machinery layouts; they also allow us to translate scientific texts from one language to another. They are capable of carrying out unaided, work which would otherwise require a host of mathematicians, calculators, and accountants. In the near future, marvellous information machines will be created which will receive and circulate a vast quantity of news items. At our behest, the electro-eliminator, a special mechanism in these machines, will automatically check through the entire stock and store of information contained, rejecting everything inapplicable and selecting the necessary, effecting analysis therefrom, and giving us the answer to our particular query.

'Physicists have penetrated into the treasure house of the atom cell. Work is in progress to harness thermo-nuclear energy for pacific ends. In a future still fairly distant, we shall see the creation of electric power stations which will utilize the practically inexhaustible supplies of fuel drawn from the nuclei of light elements, primarily hydrogen and its isotopes.

'The advent of the antiproton and the positron turns one's thoughts towards the possibility of creating a negative substance. . . .

'I have just mentioned a few of the contemporary matters that have become a reality for scientists and which now preoccupy them – such matters that were not even a dream a few years ago, because they just didn't exist.

'Science cannot develop without dreams and meditation upon the future. Dreams, inevitably, are the forerunners of the hypotheses which experiment can transform into a scientific theory. I am not speaking of the pipe dreams of Manilov[1] but of coherent thought about development in this or that field of science, based on what has already been achieved. Scientists' dreams constitute an incursion into a hitherto unexplored field, a scientific prognosis of the future, that can be very bold, very protracted in time, but which must, above all, have solid foundations.

'Normally, scientists are loath to speak of their dreams because it is more rewarding to complete a task before talking about it; and yet, you know, their unfulfilled dreams could be extremely valuable. They could serve as beacons which the scientist perceives as he looks far along the road to the future; those who are to tread that path subsequently would at least have those beacons as guides, and indeed, how many youthful scientists-in-the-making would be unable to resist their lure!

'I wish to stress that to dream is not the prerogative of great scientists. It is more a characteristic of youth, and youth must ceaselessly nurture and develop it. We live in a country where the boldest dreams come true. But the dreams can only be realized at the price of great efforts, and only hard work will be rewarded by success; without assiduous work, perseverance, and constancy it is impossible to enter the realms of science. It is only by dedicating oneself entirely to science that one can make an independent step forward. Normally, youth is bold in its dreams. The most difficult thing for the young is to restrain a flight from present-day actual possibilities. For the dream to bear fruit it must have firm, sound roots. But the greatest danger of all is something totally different: it is *not* to look ahead,

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[1] Manilov was a character in Gogol's *Dead Souls* notorious for his indolence and the amiable but vacuous nature of his reflections.

not to see, and *not* to set for oneself a bold goal. Youth must learn both to dream and to realize those dreams.'

Alexander Nikolaievich paused for a moment. The stenographer put down her pencil. At the start of our conversation we had asked the professor to tell us something about prospects in the development of organic chemistry. He had dedicated his whole life to this science, or to be more exact, to one of its branches – metallo-organic chemistry. His works in this field have been translated into many languages. One of the most remarkable reactions ever obtained in the synthesis of metallo-organic compounds is known by scientists the world over as the 'Nessmayanov Diaz Method'; so surely he would not fail to say a word or two about future prospects in that most marvellous of all sciences, the science of prodigious transformations – chemistry?

'I shall now reply to your second question – about the future of organic chemistry,' said Nessmayanov, who seemed to have read our thoughts. 'It is a science which is developing rapidly, one which has achieved much and will achieve infinitely more in the future.

'In the initial stage, organic chemistry, which science was born from the fusion of "vegetable" and "animal" chemistry, confined itself to the study of matter obtained from organic nature. But as long ago as the sixties of the last century it embarked on the path of independent creation. Its first victory consisted in the reproduction of substances which are to be found in organisms. Now, the means used to achieve this creation had nothing in common with the processes of the vegetable and animal kingdoms. Thus organic chemistry set out on its own basic course, in other words that of synthesis. With synthesis as their principle, chemists were also able to produce organic substances not to be found in nature – synthetic fibre substances, such as "kapron" (caprone), for ininstance; or explosive substances, like trotyl and nitroglycerine, that are so widely used in industry. Zoologists know no animal whose wool consists of caprone; nor have botanists ever seen a plant whose tuber or seeds secrete trotyl. The molecules of these and of many other organic substances which do not exist in nature – medicinal substances that are more effective than natural ones, internal combustion engine fuels of high quality – have all been created by man. This was the second great victory of organic chemistry.

'Radical changes in the dye industry afford a good illustration of what a revolution in technique has been wrought in the wake of these victories. Pushkin and Gogol wore clothes the colours of which were obtained from animal or vegetable dyes. In this respect their clothes did not differ from those worn by the Ancient Egyptians or the Romans. These days, our clothing contains not one single thread that has been treated with such products. The dye used in the suits you are now wearing is exclusively artificial or synthetic.

'At one time large tracts of arable land in Central Europe were sown with madder from the roots of which was obtained alizarin to colour tissues Turkey Red. This alizarin dye of vegetable origin has now practically gone out of use and to take its place there is a range of much more perfected chemical products, totally different in content from the vegetable counterpart. The same applies to the cultivation of vaida (isatin) and other indigos from which blue was obtained. Rubber tree plantations will undoubtedly meet with the same fate. There already exists today a complete range of synthetic rubbers; of these certain varieties resemble the natural product, while others, in greater or lesser degree, possess natural rubber's properties and structure; then, others again have a composition that shares nothing with it at all – in fact, they have some very valuable qualities quite non-existent in natural rubber. For most people, the transformation in the dye industry at the end of the nineteenth century, when in the course of two decades natural dyes were replaced by synthetic ones, passed unobserved. Similarly, it is by no means everybody today that notices that even more striking substitution of many substances in common use by the synthetic.

'Many things of which people dreamed in past centuries, even in the past few decades, have become reality and left the realm of fantasy for the world of today. It would seem as if the general use of artificial fibres came upon us almost by stealth. When we don an artificial silk shirt, we are apt to forget the marvellous transformation of pine wood into the shirt's pliable tissue. Even more interesting are the completely synthetic fibres obtained from materials which have no connexion with organic nature. Caprone, nylon, polichlorvinyl, and many other fibres – more elegant, stronger, and more hygienic than the natural article – are used today on a large scale by the textile and footwear industries. As you know, recently an artificial astrakhan from "anid" (nylon) fibre was introduced in this country. Synthetic fur is better than the natural, just as synthetic leather is better than natural leather. There is no doubt that in the future, natural fibres, furs, and leathers, in the same way as natural dyes, will be superseded by artificial products. Our chemists can, and undoubtedly will, create fibres and tissues with given properties prescribed prior to manufacture, which will be of a calibre incomparably superior to that of natural materials.

'It is safe to say that in the twenty-first century, people will be clothed and shod exclusively in artificial materials; and in a general way all the objects surrounding them will be of artificial materials too.

'Even now we are making wide use of materials that were never known to Nature. Your fountain pen and comb, your radio set and the light switches are made of plastic. Never did the most intrepid adventurer and explorer return from his travels to describe plastic rocks, plastic tree trunks, and plastic horns of beasts! This material has been created by man without imitating Nature, but it corresponds more to our requirements, and has better properties, than Nature's alternatives; so now it is beginning to oust them all along the line.

'Whole periods in the history of the human race bear the name of the principal substance which men used in the various stages of their civilization. There was an age in which stone, crudely shaped by means of another stone, was man's only instrument; this period in the history of man lasted many thousands of years and was called the Stone Age. This was followed by the Bronze Age and the Iron Age. But quite apart from this conventional method that history uses for indicating periods, I can say with conviction that we have now entered the age of artificial materials, the Plastic Age. Plastic materials as strong as metal have already begun to usurp the place of metals in production processes; new plastics have been discovered having the same resistance to acids and alkalis as platinum. Plastic is now used in sculpture and will gradually replace marble. In the new Moscow trolley buses, the windows, instead of having the usual silicate glass, production of which goes back to the times of the Phoenicians, are fitted with a type of organic material that is far lighter, more transparent, and permits the infiltration of ultra-violet rays. Beautiful, resistant plastic materials may eventually oust veneered woods in furniture.

'The interior finishings of the present-day motor car are made in a type of plastic that imitates wood. In the twenty-first century it will be difficult, not to find objects made of plastic, but to find objects made solely of natural materials in their virgin condition.

'All the conquests of organic chemistry I have just quoted have been achieved by processes quite foreign to the ways of organic Nature. I have already mentioned that in the initial stages of its development, organic chemistry embarked along a path contrary to that of Nature: it has imitated Nature by creating her substances, but has not imitated her methods of arriving at those substances. Now, organic Nature goes about her own synthesis in a most tantalizingly rapid and simple way. We have only to consider the work of our own digestive system, which grinds down our food into tiny, microscopic "building bricks", which the body's synthetic process uses to build up all those most delicate and intricate tissues of muscle, bone, and brain – we have only to consider that, to appreciate what Nature can do.

'Synthetic rubber is obtained by a method which has nothing in common with the rubber tree's natural processes. For the different operations in a synthetic rubber factory, a very high temperature is often necessary; but in the living cell there is a process wherein at each stage the most minute and delicate action or influence of various enzymes directs and accelerates the general reaction. The mastery of these ways of Nature – of these most complicated mechanisms of chemical transformation – will be the third great victory of organic chemistry, which in future will tend to merge with biochemistry. I am convinced that chemistry will celebrate this victory during the present century.

'Quite early during this new stage in the history of organic chemistry – enzymotic chemistry – we shall probably master the production secrets of Nature's living laboratories. Then eventually, at a time that is yet a long way ahead, we shall employ those very processes that are peculiar to Nature, for the purpose of obtaining matter that is non-existent in Nature.

'To recapitulate, in the history of synthetic organic chemistry we can observe the following basic stages: the first stage is the synthesis of plant and animal matter by means that are quite foreign to Nature. The second stage is the creation by similar synthetic methods of an infinite variety of substances which Nature does not possess. The third stage, which we have reached today, is the creation by the methods employed in Nature (enzymotic methods) of substances which are contained in organisms. And finally, there is a fourth stage, still wholly in the future, when, from the employment of Nature's own enzymotic methods, there will emerge substances that are none the less quite unknown in Nature, and to achieve this we shall also have to create enzymes that will be likewise unknown to her.

'Today it is difficult to foresee what practical results will come about from pursuing these yet unexplored paths; but it could well be that even more wonderful things could emerge than anything I have spoken to you about. Perhaps, through probing the chlorophyll grain's secrets and those contained in intercellular transformations of matter in living organisms, we shall arrive at a factory technique for artificial food products which will be vastly superior in quality, expediency of composition, and assimilability to the natural food we eat today. By that time, there will be a man-made way of using solar energy far more effectively than merely through the intermediary of plant life.'

CHAPTER 2

Concerning Basic and Principal Things

THE aim of any activity is to benefit mankind. Everything is aimed at satisfying in the completest manner possible the needs of our society and of each individual. What is required first and foremost to satisfy these needs? In what do they consist?

A moment's simple reflection will make us see that man needs, first and foremost, food, clothing, and shelter.

Of these three needs, the primary and most essential is food; let us, therefore, see what has to be done in order to satisfy that need in its very commonest form of all – bread.

Each day we buy from local provision shops, which take deliveries of it from one of the large modern bakeries serving our locality.

The modern mechanized bakery is a colossal concern equipped with a host of mechanical devices and machines. The machines sift the flour, weigh and mix it with water and yeast into dough and then into loaves, which are baked in the ovens. All these machines are driven by electricity and are made mainly of metal.

The first conclusion we can draw is that to ensure the baking of a vast quantity of bread we must build a great number of mechanized bakeries.

But the mechanized bakery cannot work without its supplies of materials, foremost of which is flour. The flour comes from mills, which likewise are highly mechanized and driven by electricity.

To ensure that the bakeries receive their flour, therefore, flour mills are essential.

The flour mills, in their turn, need raw material by way of grain, which latter is harvested on the vast fields of collective farms by reaping and binding machines. In order to harvest vast quantities of grain without incurring loss, an adequate stud of these reapers and binders must be kept at hand on the farms, and naturally, there must be sufficient fuel stocks, both for the motors of these machines and of the tractors that are also so indispensable at harvest time.

In order that the farms can grow plenty of corn, the earth must be well tilled, treated with chemical fertilizers, and a war against insect pests must be carried on from aeroplanes, either by dry dissemination or liquid spraying; all of which operations, too, involve the internal combustion engine, with the consequent requirement of fuel.

Let us recapitulate. We see that throughout bread production from field to bakery, the machine in some form or other is omnipresent. Thus, in order to augment the number of all those machines – flour mill and bakery equipment, agricultural machinery, and so forth, whereby we can guarantee a sufficient supply of best quality bread – the most vital necessity of all is an expansion of the heavy machine-building industry.

Today these machines are made of metal, mainly iron and its derivatives. For the production of metals we need coal. This, in turn, means that to obtain the requisite quantities of our rye and wheaten bread we must at all costs develop the metallurgical and coal industries.

The power that turns the wheels in our mills and factories – inclusive of those involved in bread production – is electricity; and so more and more power stations must be built to throw out far and wide their tentacles of pylons. Then, as agricultural machinery of all kinds is based on oil fuel, we realize that both agriculture and the food industry proceeding therefrom are most vitally concerned in the further development of the oil industry.

Chemical fertilizers, weed destroyers, and insect destroyers are of inestimable value for improving the yield year by year; it follows, therefore, that agriculture is vitally linked with yet another industrial question – that of a further build-up in the chemical industry.

Apart from food, take practically any other article of daily need you may like to mention, and from an analogous course of reasoning you will find that those very same industries have played their part in bringing it to you: the metallurgical, coal, chemical, electric power, and machine-building industries.

These fields of industry are the bases of our economy, upon the development of which depends the benefit of the nation as a whole, and of every man, woman, and child, in particular. In actual fact, metal is the basis of modern industry. The structure of industrial buildings, of houses, bridges, dams, and power stations, the mechanism of clocks and the enormous steel ingot rolling mill, the high voltage power lines, the gas pipes, and the rocket which roars into the ionosphere beyond the clouds, are all of metal. The mining industry which extracts the ores, the smelting industry which turns out steel and sheet metal – all these constitute our heavy industry.

Lenin used to call coal the 'bread of industry'. In actual fact, three-quarters of the electricity produced in our country comes from thermal power stations using coal.

Coal, or to be more precise coke, is essential for the working of blast furnaces. Lastly, coal is an extremely valuable raw material in the chemical industry. From it are made dyes, medicinal preparations, liquid-fuel, certain aromatics and explosives, etc., etc.

The coal industry forms part of heavy industry. For the lathes and other machine-tools of a large modern factory to start functioning, electric current must be supplied to the motors that drive them. This is the fiery life-blood of industry, the flow of which sets in motion countless different kinds of machines and appliances. The provision of power for industry – electric power above all – may in itself, beyond doubt, be said to constitute one of our heavy industries.

The life-blood of the internal combustion motor is, of course, oil – refined as petrol or otherwise. This is the power that, in the form of brown, oily drops, explodes in the cylinders to drive those many thousands of tractors that we see taking to the fields in spring. This is also the power that sends both motor cars and heavy diesel tipping lorries along our highways, the power enabling the jet aeroplane to pursue its course with such incredible speed and fury.

Thus oil, both in its extraction and its refining, indisputably belongs to heavy industry.

But the key to all industry, heavy and light, the key to transport and agriculture as well, is the engineering or heavy machine-building industry.

The basic factor above all, of our economy, is heavy industry, for without it, all other industry, transport, and agriculture would be paralysed. It is, let us stress, the very foundation for development in any and every aspect of our country's economy.

That is why we began our reportage on the twenty-first century by visiting such enterprises as smelting works, oil wells, coal mines, and engineering works. Hence also our interest in matters like the power balance of A.D. 2007, developments in the electro-technical sphere, and the subterranean gasification of coal.

CHAPTER 3

Transformation of the Elements: The Future of Metallurgy

'EVERY science, including the most abstract and the most theoretical, is born of a real and genuine need. Astronomy was born from the need of exact navigation. Geometry served the farmers to measure their arable lands. But probably one of the most applied sciences which has never broken its bonds with practice is the science of metals. . . .'

We were speaking to Professor Ivan Pavlovich Bardin. He is a man of over seventy. We visited him at the end of his working day. He looked weary but his face lit up and his eyes recovered their youthful fire when he pronounced the words: 'The science of metals.'

Bardin came of a poor family that never dreamed of giving their son an education, and he was encouraged to devote his life to the study of science by a maternal aunt and her husband, the former a school-mistress, and the latter a student.

Bardin's biography is the story of a talented youth who lacked family ties, influential acquaintances, and inheritance, but who made the grade by his own efforts. On leaving school he was unable to find work in Russia, so he emigrated to America. There, he shoved his engineer's degree away in his pocket and began to work as an ordinary factory hand. Upon returning to the homeland, he was, in his own words, lucky enough to work with the famous metallurgist M. I. Kurako. The Revolution, he maintains, split his life in two. He was given the task of building the giant ancestor of Soviet industry, the industrial centre of Kuznetzov, and at the same time he had a vast organizational and scientific task aimed at amplifying and perfecting metallurgy in Russia. It is easy to understand that this man, who considers that the greatest stroke of good fortune in his life was to build the Kuznetzov organization, could betray a twinge of emotion at those simple words: 'The science of metals . . .'

'This science,' Ivan Pavlovich told us, 'was born many thousand years ago, when man began to use such natural nuggets of metal as could be found. Later, he learned how to extract metal from ores, and even today he continues to explore this sector. The search for new methods of recovering metals and metal products from various minerals is still one of the most important problems of metallurgy. As you see, in its long life, this science has not yet exhausted itself.

'Can we maintain that the modern technique of obtaining the most universally used metal, that is to say iron, is the best one?

'The normal pattern of this technological process is as follows: the iron ore is enriched, placed in a blast furnace where it is mingled with coke, and then allowed to heat. The iron is "regenerated" and saturated with carbon; from the blast furnace we obtain pig iron. This pig iron is smelted in furnaces where the carbon is extracted in special stoves, leaving ingots of steel. Before introducing these into the heavy cylinders of the rolling mills, the metal still has to be heated more than once. Why not eliminate from this technique all the intermediate processes which consume much energy, cause a great deal of hard work and are very costly; and obtain from the ore pure iron or steel to specification in the form of finished products – lines for railways, channel iron, or flanged beam? Instead of the present process which is all so broken up into separate stages – preparing the ore, smelting the pig iron, transforming it into steel, and so on and so on – instead of all that, why not have an unbroken, continuous process?

'In my view this is possible, and metallurgists of the future will reject the present-day techniques. The modern blast furnaces, the Martin furnaces and the Bessemer converters, the rolling mills – all those accessories of present-day practice, will be eliminated by the scientist of the future. It must not of course be thought that in the course of the next ten years or so we shall scrap the outmoded blast furnaces in favour of new apparatuses for winning pure iron. No! The blast furnace technique is not yet exhausted and it is capable of further perfection; we shall still build blast furnaces, and will continue to do so for a very long time yet. The modern blast furnace is already a very complicated affair equipped with a host of automatic devices, and operated by only very few workers. Its successor will be purely automatic. It will be controlled solely by a calculating electronic machine which has been given the required "working instructions" to embrace all possible eventualities should there be any deviation from the prescribed programme.

'In the next few years the process for obtaining metal will become continuous. Pig iron will flow in an uninterrupted stream from the blast furnace. Even today a blast furnace produces 2000 tons of pig iron in twenty-four hours – more than a ton per minute. Oxygen will be forced through the flow of newly smelted pig iron, and a bright flame will rise above the vat in which this process takes place; the flame will consume the excess carbon, sulphur, phosphorus – all the dross which spoils the quality of the metal; then, it will already be a flow of molten steel – not pig iron, that comes pouring into the moulds of the teeming machine. On leaving the moulds, the steel ingots will pass immediately to the rolling mills to be transformed into products. It would be far easier to apply automation to a continuous process than to the present process which is in stages.

'It is likely also, that in a rather more distant future – not in the next few years at all events – the whole structure of the blast furnace will undergo a radical change. The apparatus in which the formation of the metal will take place, will be a horizontal assembly in the form of a large rotating tube. Into this blast furnace from one side will be introduced the well-purified ore pulverized down to powder, this being the metal oxide devoid of any extraneous matter, and from the other side a regenerating gas – hydrogen, for example. With a technological process of this nature, it will be possible to obtain the metal in the form of a very fine powder which, after the addition of the necessary alloying elements, will pass either to a further phase of smelting, or directly into the press.

'Every creature has a given span of life. The tortoise, it is said, may live up to 300 years, while the horse rarely reaches the age of thirty. Metals also possess a given life span. Admittedly, the length of life of a metal largely depends upon the use to which it is put. The metal of a table knife, for example, will in all probability last longer than a metal used in an aircraft engine. The work demanded from a knife is normally not very arduous and the internal transformations in its structure take place at a very slow tempo; and like the leisurely tortoise, it may last 300 years. It is quite a different matter with the metal of an aircraft engine. Its life is far more hectic than that of the fastest racehorse. In the heart of the motor the cylinders are subjected to impetuous blows and explosions, hundreds – maybe even thousands – of them per minute. It is under constant stress, it vibrates and heaves – and the fact that the present-day average life of the metal used in our engines and machines is about thirty-five years represents no mean achievement in metallurgy.

'Will the life of metals be prolonged in the near future? Undoubtedly it will be prolonged in comparison with the present day. Blades of hardened steel protected by a very thin layer of oxide can last for several hundred years. Naturally, this metal cannot be obtained in large quantities in blast furnaces under high gas pressure and other unfavourable conditions reigning in a large industrial concern. But we have simply got to reach that point where our mass-produced metal is not inferior in quality to the damascened blades of the old armourers.

'Naturally, modern steel – for example, stainless steel – is far more durable than that forged by the old sword makers. But here we have an entirely different technological solution to the problem: Damascus steel did not have chromium, nickel, and the other metals added which go to make up twenty-five per cent of our modern stainless steel.

'Iron is undoubtedly the basic metal of modern technology. But the day may come when it will give place to other metals. It is generally conceded that iron could be superseded by copper, the metal of electrotechnics, by that featherweight metal aluminium, or by a newcomer which shows every indication that it can compete with steel – titanium. So accordingly, it is thought that the twenty-first century will be the age of copper, for is not electricity constantly invading new spheres of human activity? – or of aluminium (widely used, natural deposits almost everywhere, light in weight, almost equal to copper as a conductor, as strong as steel when alloyed, the metal of aviation), or perhaps the age of titanium.

'Personally, I do not believe that during the next century iron will relinquish its leading position at all easily. Naturally, non-ferrous metals will assume increasing importance and their production will be stepped up. But at the same time the quantity of iron will be increased. If in 1880 iron constituted 95·65 per cent of all metals used, after sixty years – in 1939 – during which electrotechnics and aviation had come on the scene, the proportion of iron used compared with all other metals was still 94·06 per cent. One and a half per cent in half a century – that's the rate at which iron has yielded its place up to now. It is very doubtful whether this rate will change very much in the next fifty years.

'One thing, however, is self-evident: aluminium, magnesium, copper, titanium, and zirconium will assume a more important place in our lives – particularly the two latter metals. It is generally supposed that these metals are rare; but as far as titanium is concerned, that is not so. Of the elements that go to make up the earth's crust, titanium accounts for 0·6 per cent (by weight) – it is one of the most widely diffused elements. It possesses a high resistance – twice that of iron, and yet the weight factor is considerably less than in iron.

'Titanium also possesses a further valuable property – its resistance to corrosion. The latter is the bane of metals and destroys a quarter of all the iron extracted throughout the world. Titanium, on the other hand, is almost immune to corrosion. In this respect it is on a par with platinum; it resists the action of acids, alkaloids, and salts. Even submersion in seawater for many years will not cause it to become covered with a thin film of oxide. Aqua Regia or Königswasser, which is a concentrated mixture of chloric and nitric acids, attacks and corrodes precious metals such as gold and platinum. Titanium, on the other hand, remains unchanged when subjected to this very powerful acid. By virtue of its very resistance, it may be considered more "precious" than any of the world's famous precious metals.

'Titanium is also incredibly heat-resisting. It melts at a temperature of 1725° C., exceeding, therefore, the melting point of steel by 200° C. All these properties make it iron's most dangerous rival. The production of this metal, which began in 1946, is increasing at a fantastic rate; in 1948, smelting of titanium amounted to a meagre 10 tons all told, but the total for 1954 was 7200 tons, and in the following year a formidable total of close on 20,000 tons, was accounted for! – may steel put that in its pipe and smoke it!

'We have already said that the life of steel is approximately thirty-five years. Products made of titanium or zirconium will endure for centuries and will, in fact, be almost everlasting. At the same time, they will be much lighter than anything made from iron.

'The story of titanium is not unlike that of aluminium: a pure titanium oxide, in the form of a white, crystalline powder, first became known as long ago as 1790; and yet, there had to be a lapse of 120 years before the first few grammes of it could be realized in the shape of that gleaming, silvery, steel-like metal we know today. It is a bare ten years since its industrial production began, but we already find it being given credit as the metal of the future, with the widest possible range of application – aircraft, gas turbines, space rockets, and a hundred and one other uses. I say again: there really is something here to make iron and steel put their thinking caps on.

'Now, just one thing more I should like to say a few words about: a new method of steel preparation, with a view to improving it in the mechanical respect. Of the orthodox methods, there are, firstly, those of a purely thermal nature – hardening, tempering, and annealing; then there are the combined thermo-chemical methods – case-hardening and nitriding; and lastly, the mechanical method – cold hardening. Now, experiments carried out give us reason to believe that a fourth and essentially different kind of procedure will be resorted to. This will be radiation by a current of neutrons. Steel thus treated will acquire quite unheard of and perfectly amazing qualities. The task immediately ahead of us now is to find the exact requisite amount of radiation to be applied, to get the routine details settled, and to create the apparatus.

'We live in an atomic age. Man is master not merely of the relatively feeble, uncertain, and transient atom phenomena of nature; his knowledge now extends far deeper and in a more significant direction – to the particle of the atomic nucleus itself. The achievements of atomic research can but make themselves felt in metallurgy – just as they do in many another sphere.

'It is my belief that quite an early phase of this atomic age will see man enabled to "build up" for himself through radioactive rays the equivalents of any kind of finely alloyed steel; these will contain no rare and costly alloying elements at all, but any equivalent required will be formed straight away in the pan of molten metal, the contents of which will be modified by the action of iron atoms, carbon atoms, perhaps sulphur and phosphorus atoms – or maybe atoms of some other common element specially selected beforehand and added to the molten mass of steel. I conceive the process to be something like this: the great cauldron, full to the brim with the elastic-like waves of molten steel splashing around, is seen moving along; then, suddenly, it halts for a few seconds by an apparatus not unlike those employed in medicine for curing cancerous growths by radiation treatment. A pear-shaped object made of lead is now inclined over the cauldron, and in this is concealed a radioactive ray of the requisite composition;

thus, subjected to these rays, the molten mass of metal undergoes all sorts of highly complex nuclear transformations. In a few minutes' time, the steel is poured out into the moulds, but its composition is now profoundly different from what it was only some minutes ago: and after a day or two, there will be a further change still, for in the steel – by now, of course, hardened again – there will take place a process of chemical transformation which the steel promotes by its own radioactivity, which state has, in its turn, been induced through subjection to the rays.

'It may well come about that this same method – changing the structure of atomic nuclei through artificially modifying their elemental make-up – will even permit of arriving at matter equivalent to the ores of some most rare and far-flung elements. Indeed, a whole new branch of the metal industry may appear on the scene for manufacturing, by these means, rare elements from more common ones. But rapid as metallurgical progress has been, I doubt whether even the twenty-first century will see this – it belongs to a more distant future.'

CHAPTER 4

Mining is on the Way Out

RIGHT back in 1882, the famous Russian scientist D. I. Mendeliev jotted down in his notebook a phrase which may be said to have heralded a new era in the history of extracting wealth from the bowels of the earth. This great scientist was very much in advance of his time. Today, after three-quarters of a century, we are witnessing the first practical experiments of the method described in Mendeliev's notebook: but there is no doubt at all that in the next century the new principle will become firmly established and will supersede all others. This is the phrase in question: 'Ignite underground coal seams, whereby same are converted into lighting, generating, or water gas: this to be led off to surface in pipes.'

We were talking to two people: Ivan Semionovich Garkousha the director of the Podzemgaz Research Institute, and his assistant on the scientific side, Nikolai Ananievich Fedorov. With such smooth efficiency did the pair cooperate in providing information in their respective specialities, switching over the discourse from one to the other and back again in almost mechanical fashion, that the stenographer, as transpired later, was at pains to distinguish to which man might belong this or that observation. It is only those who are accustomed to working together in the closest harmony on the same scheme or project who can supplement each other so smoothly.

On the table lay two books: the works of Lenin and those of Mendeliev. Fedorov opened one and read the phrase we have already quoted, while Garkousha took up the second volume ... 'The British scientist, William Ramsey, put forward the same idea of subterranean gasification of coal thirty years later. Lenin was familiar with the works of Ramsey. On 21 April 1913 his article "One of the great victories of science" was published in ***Pravda***. Lenin wrote in this article that nothing less than a veritable technical revolution could come from putting this idea into practice.

'But difficult years were to follow: the First World War, the Revolution, the Intervention; then the country's ruined economy had to be built up again from scratch. Lenin died in 1924, but it was largely thanks to his keen support of the idea that it eventually won through. Studying the writings of Vladimir Ilyich Lenin, the soldiers of a certain cavalry regiment asked why work had not begun on the subterranean gasification of coal. Their inquiry was printed in the magazine *Technika* and called for an answer. Detailed study on the question of underground coal gasification was begun in 1931 with a view to transforming the seams of coal into combustible gas below ground. It must be pointed out that this is one of the most complicated problems of modern technology and it comprises practically every branch of science: the mining industry, chemistry, electrotechnics, mechanics, automation, etc. It would be no use trying to find a rapid solution in a formidable matter like this. We must consider it a great success that by the beginning of the Second World War our scientists proved that it was possible to realize Mendeliev's ideas. This means that in the future it will no longer be necessary to sink mine shafts, and the miner's underground drudgery will become a thing of the past.

'In the first post-war years, scientists again took up their investigations of the matter, but the whole problem was now viewed in a different light. The pre-war experiments were conducted by excavating in the seams a small gallery with vertical shafts rising to the surface at both ends. The gallery was then set alight. This meant that some five to ten per cent of the work had to be done underground, and the process was thus considerably complicated. The task we have now set ourselves is that of preparing the seams for gasification, without resorting to any shafts or excavations at all – in other words, we have decided to eliminate underground work altogether.

'But how is it possible to drive a horizontal gallery through a coal bed without descending into the earth? Today we know of more than one way in which this can be done.

'If two openings are bored at a certain distance from each other, and if air is forced down one of them, then some part, at least, of that air stream thus caused to penetrate all the cracks and crevices of the seam, will find its way to the neighbouring opening, whence it will issue; then, if this point of issue is ignited, the combustion centre will begin shifting at the approach of the oxygen that is gradually advancing meanwhile from the other opening, and will proceed against the air stream, making its way right through to the opening down which air is sent. Thus, the horizontal passage that is burned through from bore to bore may be regarded as substituting the horizontal excavation that would be made from shaft to shaft in pre-war days. This method was tried out in the Central Region coalfield, and is now being widely applied at one of our "Podzemgaz" stations at Tula.

'The coal seam's degree of density is a factor that can render necessary an increase in the air pressure in order to effect penetration as far as the neighbouring bore; the increase in pressure may have to be up to twenty, fifty, or even a hundred atmospheres, according to conditions.

'The disadvantage of this method is the high amount of unproductive compressed air which simply disperses in the seam; but the general economic gain from gasification permits one to countenance that amount of wasted energy.

'Another method is to have the borings circuited with electrodes. If electrodes are introduced through the shafts and a high tension electric current is applied, the coal is turned into coke when its temperature reaches 1000° C. – but naturally, not the entire seam. Experiments have shown that small veins of coke about the width of a pencil are formed in the coal, constituting an excellent conductor of electricity. In due course, the electric current passing through the seam gives rise to a phenomenon in the nature of underground lightning, and it is this that creates the horizontal passage.

'There is one more method that we have in view for preparing the coal seams: horizontal boring. This is really not quite so outlandish as one might think; in our institute, we have already turned out the prototype of a turbo-drill for this kind of work. But none the less, it is certainly not a simple matter: you see, it will not only be a question of the actual boring, but also of making sure that the whole length of the bore is kept within the seam – of course, the ideal thing would be to get it passing plumb through the middle.'

The two scientists opened an album of designs, plans, and diagrams. They drew our attention to one of these drawings, showing a curve resembling a parabola with its vertex resting on a horizontal coordinate.

'Here we have a graph that illustrates the presence and distribution in a coal layer of a quantity of elementary particles, such as are formed in the strata as a result of its natural radioactivity. A layer of coal will lose no time in absorbing the elementary particles that find their way in from the surrounding strata. The nearer we go towards the heart of the coal layer, the smaller amounts of detached and unabsorbed particles do we find; thus, their minimum number coincides with the centre. Now this is a circumstance that we want to turn to good account and make use of, so that in conjunction with just the right kind of guiding instrument it will cause our turbo-drill to take a course through the very centre of the seam; and we are now hard at it on the problem of determining this instrument.

'Now, there is just a point here that it is essential to have in mind: the boring of vertical holes or openings by mechanical means is no longer to be considered either as the only or best method of penetrating the strata, and where that question is concerned we may now anticipate some absolutely revolutionary innovations. Our own view is that high-frequencies will assume a very important role here – the application of a guided "spray" antenna. We also think that there are great possibilities here in the supersonic field.

'However, let us now talk about the next century, by which time, we feel quite sure, man will no longer have to descend deep into the bowels of the earth to extract its treasures. Then, perhaps, the only people who will venture underground will be scientists engaged on experiments in their quest after Nature's secrets.'

By now the two men were visibly under some stress; it almost felt as if they were divulging something ultra-confidential – something they cherished so much that it could have been sacred. We recalled what A. N. Nessmayanov, President of the Academy of Science, had said to us when we told him of our wish to induce scientists to unfold their dreams: 'You would pick upon something by no means easy, if you set out to do that,' he told us. 'Naturally, scientists build their castles in the air, just as others do – they are not strangers to anything that is human, in fact; and for that matter, girls dream too, and it is by no means every girl who will disclose her dreams – not even to her closest friend!'

How high principled, how enviably modest is the scientist! – for are those not the qualities that will make some silent, unassuming laboratory toiler check and test dozens and dozens of times over the great discovery he has made and which nobody else yet knows? – is it not, perhaps, due to that peculiarly unassuming view he takes of his creative work, that in the outside world he may often be taken for a dry, hard, wooden, and unimaginative being? But we who have met numerous scientists and had heart-to-heart talks with them, know better – we could see that in every one of them, men of few words as they mostly were, the flame of inspiration and high ideals burned bright behind the shy façade – and it is thanks to that same flame that Soviet science is now supreme in the world, both in daring, breath-taking thought and project, and in solid, magnificent achievement.

Most likely, passengers in the twenty-first century superspeed, stratospheric air-train will gaze down in some perplexity at the huge, pyramid-like mounds of earth that are seen to abound in the Donetz region, in the Kuznetsk Coalfield steppes, and in many other localities. 'These great mounds or hillocks are the slag-heaps of former coal-mines; they stand in silent witness of that period in technology, when man had to go deep down underground and toil away in cramped, burrow-like passages with all sorts of clumsy tools and instruments, in order to get coal.' So explains an engineer to his travelling companions in the stratospheric conveyance. 'As you see,' he goes on, 'the mounds are well planted over with flowers, so as to prevent any dust nuisance and incidentally to serve as parks and botanical gardens which beautify the towns – for even now, you know, all these places are thickly populated, and there is a thriving industry using as its raw material the underground stores of coal which are yet far from being exhausted.'

Among the passengers of the air-train there are bound to be people who want to know about the activities of these huge concerns seen from the air, and the engineer tells them: 'Coal is still one of the most precious gifts of Nature. It is used just as it was fifty years ago as a source of energy, and in many chemical products. But if, fifty years ago, coal had to be extracted in bulk from under the ground and transported on the surface, thereby constituting a colossal burden for the railways – if, at every thermal power station, at every large railway station, at every boiler house, there had to be enormous stores of coal – then today, to see such a thing as a piece of coal, one must go to a geological museum. These days, no matter whether it be for power use or chemical use, coal only comes to us in the form of gas, obtained through underground gasification. In recent years, too, this gas from under the ground has been increasingly directed, in the first place, to power-technological aggregates in order that there shall be the absolute maximum degree of economy and productivity in making use of it. By the way, I have with me a cinema film of one of these aggregates; allow me to show it to you.'

The light is put out, and an improvised cinema seance begins in the comfortable saloon of the stratosphere train as it hurtles on through the rarefied layers of the ionosphere at incredible speed. Let us suppose we have joined those travellers of the twenty-first century, and are watching the film with them.

Along a road leading through green cornfields, a procession of several curious-looking machines, propelled by 'Caterpillar' belts of shiny metal, is seen to be moving. They are not driven by anybody, and yet, having reached what is evidently some prearranged spot, they suddenly come to a halt, after which some curious manoeuvres take place: two machines – to all appearances identical ones – move into position, so as to confront each other at a distance of rather more than 100 yards. Then almost immediately, above each of them is raised a lightweight, network aerial mast. A third machine now takes up a position midway between the other two, and proceeds to unfold a pair of wide wings.

'This assemblage of machines,' explains the engineer, 'constitutes the necessary plant outfit for automatic underground gasification. In accordance with the schedule drawn up for working the coal seams, the control-room overseer on duty has "instructed" these machines, through the electronic calculating units incorporated in them, to proceed to a certain point and to ignite the seam there. Now look!' – the engineer's illuminated pointer-stick shot out suddenly to lengthen his arm, as it were, and indicated one of the machines on the edge of that assemblage – 'this machine here is the one for boring down into the seams, which it does by means of high-frequency current. The guided "spray" of high-frequency current radiation is capable of turning the very hardest rock into fine sand. The sand thus arising is expelled by a stream of compressed air which is kept constantly directed on the working surface – and here, in this box, is housed the compressor-unit for providing the air; then here, we have the high-frequency current generator – ' and on the cinema screen, the dancing light-spot of the engineer's illuminated wand went on to jump from one part of the machine to another, as he explained each in turn.

The machines continue their routine functions; the boring proceeds without interruption: there is no question of replacing the drill of the high-frequency boring machine, as it cannot get blunt; neither does there have to be any halt in the work in order to lengthen cables, tubes, etc., for the attachments, both to drill and to compressed air nozzle, are unwound by degrees from large winding drums. The controlling instruments are fitted with dials which show the depth attained – 30, 50, 70, and finally 100 metres; so by now, there can be no doubt that the coal seam scheduled for gasification has been pierced. A few more manipulations are gone through, then suddenly the third machine – the one with wide-spreading wings – comes to life: it moves slowly along in the bee-line between the two boring machines – as well it might, for this is the machine that focuses 'sprays' of high frequency current beams to a depth of a hundred metres below ground, thus 'burning in' the first horizontal gallery connecting the two vertical bores.

This latter machine functions on a simple principle: as is well known, when a lens is directly exposed to the sun's rays, the effect obtained is a concentration of those rays into one point, where an exceedingly high temperature may be reached. Now, the layers of soil are, of course, quite impenetrable to ordinary rays of light, but they are by no means proof against certain varieties of radio waves; so what this machine does, is simply to concentrate its ultra-powerful 'spray' or 'bunch' of high-frequency current beams in such a way as to focus them deep down under the ground in a seam of coal, at which focal point a great heat is speedily developed.

'To us, all this may appear well-nigh incredible,' said Garkousha, 'but in the next century, people will be quite unmoved as they watch such driverless and completely unattended machines going about their most complicated tasks without a single hitch, and in accordance with the works management's schedule.'

The foregoing machines are followed by another which leaves behind it a shining thread of steel tubing. A few moments ago, this tube, made of flexible metal plates, was flattened out and rolled up like a fire engine hose. And now the end of the tube has been attached to the corresponding socket of the machine.

For all their clarity, the quick film 'shots' that are flashed on and off become hard to follow, and the engineer's commentary is confined to brief generalities. At length, however, he announces that the seam is ignited and the gas has begun to flow through to the works. He goes on to say: 'At the dawn of gasification – about fifty years ago – the gas which issued from the depths at a temperature of about 600° C. was immediately cooled with river water and the heat which the gas acquired in the bowels of the earth was lost. But now, we no longer permit ourselves such extravagance – although we still cool the gas, and you saw in the film how the birds settle without fear on the barely warm metal of the tube. But we cool it in special batteries containing elements of semi-conductor material which generate current. The thermic energy which issues with the gas from the subterranean gas generator is more than sufficient to provide motive power for the plant and machinery of the whole works.

'The process that takes place underground is varied in accordance with the extent of the demand on the gas that the works has to meet, hence there can be variation in the actual composition of the gas issuing from below. Moreover, the rare and dispersed elements sometimes found in the coal – which in the old days could not be extracted – are now recovered by our gas technological stations, and in the lists of their different products may be noted nearly half of those names that figure in Mendeliev's schedule. In addition to this there are synthetic dyes, liquid fuel, spirits, fertilizers, explosives, plastic materials, and many other products. They are all by-products of the gas, incorporating this or that element of it.'

On the screen now appears the works showroom at some gasification centre. In jars and phials are samples of finished products turned out there. So copious a collection of names would indeed be the envy of any branch of industry in the mid twentieth century!

But it is not only in railway tank wagons and so forth, that the centre despatches its production: from the power producing departments, where the valueless residue of the gas is fed to gas turbines, high-tension power lines radiate far and wide. We recall how, fifty years ago, nearly one third of coal production was consumed by the insatiable steam locomotive; and it is quite true that power derived from coal still continues to send locomotives along the steel highway; but these are now electric locomotives, which are so much more powerful and economical than steam ones – in fact, the latter may only be seen preserved in museums.

Pipes also, besides high-tension cables, convey a large proportion of the output: if you follow the thread of one of these pipe-lines, the chances are that it will lead you to some foundry or smelting works; for it is gas, not coke, that is used in twenty-first century furnaces, and the metal that they turn out is incomparably superior to the old pig iron of former times. How curious it is to reflect that some fifty years ago nearly a quarter of our country's coal production had to be used to meet the need for industrial coke!

Our stratospheric conveyance gave a slight jerk as it nosed downward a little, and the pilot proceeded to land it down to earth, the operation being accomplished without any of the passengers noticing it. On the small cinema screen before us there appeared the green shrubberies of a park, with bright and airy-looking buildings rearing up above them; a good three-quarters of its exterior had the appearance of being made of glass; glistening pipe-lines of rustless metal were seen radiating from it. The spick and span condition of those pipes, despite continual exposure to the elements, certainly bore witness to the fact that at last a means had been found of preventing the lion's share of all metal in existence from being sacrificed to that fiend: corrosion. High-tension pylons were also seen leading away from the building; and at a railway siding that flanked one of the walls stood a row of flat open trucks; on to these, automatically functioning cranes were busy loading up neat piles of boxes and cases. Then one upon another follow quick glimpses of the various aspects of this hive of industry, where, strange to say, hardly a human soul is to be seen. . . .

'This,' announced the engineer, 'is an automatic, power-technological works – a truly superb twenty-first century achievement.'

The conclusion of our flight had been practically simultaneous with that of the film; and now we found ourselves back in the Principal's study at the 'Podzemgaz' offices, gazing into the intelligent and shrewdly narrowed eyes of those two men who had given us this picture of the future.

'Coal,' said Garkousha, 'is still one of the most valuable of all minerals, and there is still no other source of fuel that is used to anything like the same extent. It is the basic fuel for power stations and, of course, the steam locomotive; and even when the latter has become a thing of the past, the railways will still be one of the main consumers of coal, as the current for electric locomotives will be supplied by thermal power stations. The metal industry is another big consumer – it takes nearly a quarter of our output. The most important of our present-day metals, pig iron and steel, could not be produced without coal; the chemical industry, also, is making increasingly heavy demands on it, requiring it for liquid fuel, dyes, medicines, plastics, lubricants, perfumery products, to mention only a few things. There is no doubt that our country's requirements in coal will go on growing and growing; but it is equally certain, too, that the day will come when coal will no longer be mined, and underground gasification will replace coal-mines everywhere. The needs of all categories of present-day coal consumers could be met to an absolute nicety through gasification, simply by serving them with gas of the right composition for their particular purposes – an infinitely more efficient raw material than crude coal.

'To run electric power stations on coal gas from gasification would really be of untold advantage: no more need to pile up huge coal stocks, better hygiene, higher output – the same things, in fact, that are to be observed on the railways after a change-over from steam to diesel traction. As for the metal industry, it has gone as far as stating that it would much prefer to have blast furnaces worked on gas, rather than on hard coal – and for that matter no objection would be forthcoming from the chemical industry, either, to having coal needs met by gas.'

'The great idea of Mendeliev, which Lenin was so enthusiastic about,' said Fedorov, as we prepared to take leave of him and his colleague, 'is only one of a number of ideas that are going to result in absolving man altogether from having to toil and sweat below the ground. We are absolutely convinced that in the next century, coal-mines will be non-existent; and although we don't know quite so much about the mining of minerals other than coal, we think that the dawn of the next century will see the end of all underground work in the iron ore, copper, and salt industries – for after all, take sulphur: that's a case where the shaft and mine principle has already been done away with – in our time; these days, sulphur is obtained by forcing hot steam down openings in the ground; this melts it, then the heavy yellowish liquid is pumped out through pipes. In the case of table salt, a very similar method is employed: water is simply pumped down into the ground, following which a potent brine solution is pumped out. It is highly probable that analogous processes will be resorted to in the case of other mineral ores by pumping down the appropriate acids or lyes and thus dissolving them underground.

'However, all things considered, we have the utmost confidence in asserting this: there is going to be an end to man's hard underground drudgery.'

CHAPTER 5

Oil Through Automation

THE dispute as to the origin of oil – mineral oil – has gone on unabated for many a year. According to one theory, its formation took place from certain vegetable and animal remnants that had slumped down to the sea-bed; but another theory is that oil originated in the interaction of certain primary carbohydrates and metal carbides in the deep crevices and fissures of the earth's crust. This latter, inorganic, theory was defended by Mendeliev, and he carried out experiments that indeed went far towards confirming the possibility of an oil-like substance being formed through the interaction of inorganic matter.

But the experiments of other scientists spoke no less eloquently for the organic theory – for the feasibility of animal and vegetable matter becoming transformed into oil-like substance.

It would now appear that the organic theory has won the day, and taking this theory as his basis, the Soviet scientist and academician, I. M. Goopkin, pointed out fresh localities where the existence of oil-fields had never previously been suspected, but where, he nonetheless estimated, they must be present. Subsequent prospecting has proved Goopkin to be quite correct in this, so what more convincing evidence could we have of the soundness of the organic theory?

But there are still plenty of unsolved problems concerning oil – its origin, the structure and extent of oil-fields, etc., etc. There are also numerous matters of oil-well practice and oil refining that await a satisfactory solution. How much present-day oil extraction methods leave to be desired, may be seen in the fact that no more than a meagre fifty per cent yield can be won from each oil-bed exploited. Generally speaking, the oil industry is yet very far indeed from anything like an ultimate state of perfection. In the next few years, no end of new ideas, inventions, initiative, and hard work will have to be put into this industry.

We are now at the premises of the Institute of Oil attached to the Academy of Science, and are in conference with two very distinguished oil specialists: S. I. Mironov, Academician, and M. A. Kapelyushnikov, Associate of the Academy. Behind both of them lie many years of scientific research and labour in their subject; but like all true scientists in any field, they look ahead, and not back.

'Of all minerals, oil is going to be the most important in the next fifty years or so,' said Mironov, '– oil production will keep on steadily growing and outpacing that of any other mineral. This assertion can be justified in several ways: firstly, oil is an extremely valuable fuel, decidedly richer in calories than coal, and unlike the latter which has to be mined underground, oil is obtained at the surface through boring. Secondly, oil is of the greatest value to the chemical industry as a raw material. Already, we have hundreds, even thousands, of names of products that are derived from oil, and very soon there will be thousands and tens of thousands of them. At the present time we have wrapping materials such as polyethylene and cellophane that are derived from oil; these are much used for wrapping meat, fats, and other food products; and before long, who knows, but that fats, sugar, and other essential food products will themselves be obtained from oil, so that not only the wrapping but also the contents of the parcel that the housewife carries home will be oil by-products!

'Oil, of course, is a raw material for making plastics; and plastics, as you know, are ousting metal, on the one hand, and wood and stone on the other. The numerous advantages of plastics make it an extremely valuable material for mankind. The next century will undoubtedly be the age of plastics, just as the present one is the age of metals. People will be fed, clothed, and given winter warmth by oil – through its by-products. Such products will even play an increasingly important part in building and tool and instrument manufacture.

For science and industry oil will become more valuable by far than gold.'

Kapelyushnikov now takes up the theme, and then Mironov goes on again; so we cease to notice who is saying what, and simply concentrate on the general line of the narrative and the basic ideas put forward.

'Now, the years ahead of us are bound to bring an ever mounting demand for oil, both as the chief fuel for all kinds of transport purposes – motor ships, diesel locomotives, aircraft, motor cars, tractors, etc., etc. – and also, of course, as a very valuable raw material for the chemical industry. So when all this is borne in mind, it may not be unnatural to wonder if there can be any danger of our mineral oil resources drying up – and assuming a future civilization that had become more and more dependent, both directly and indirectly, on oil, such a prospect could imply a threat to its very further continuance.

'But may such misgivings be banished from our heads once and for all! Thirty years ago scientists would have fearsome visions as to the consequences of Chilean nitrate becoming exhausted, this being a valuable fertilizer containing nitrogen in cubic form; but now we simply obtain nitrous fertilizers from the air we breathe! Actually, there were some hasty and short-sighted calculations made about twenty years ago according to which all oil supplies would be exhausted in fifteen years' time from then – well, we know how much of that has come true!

'Our country is very rich in oil – and yet it was not so long ago that we thought our only oil-fields were in the Caucasian region. Now oil is being extracted in Central Asia, the Volga region, and in the Ukraine. Prospecting has now begun in White Russia; and as yet Siberia has far from revealed all the oil she contains; hot subterranean gases have been found there, and oil must undoubtedly be there as well. We can say with confidence that for the whole of the next century at least, however much the need for oil increases, there will be more than sufficient of it in the sources of supply that are already known. As for the latent amount of oil in our country, we could only form an estimate by knowing first of all the total quantity of precipitated rock deposits throughout the length and breadth of the land. The calculations that are being made on this matter are not yet completed.

'What are the greatest depths that could be attained in oil boring? In America, I understand, a bore has been driven to the depth of 6,500 metres; the greatest depth yet reached in this country is 5,000 metres. In so far as such bores as these yield up oil, we have confirmation beyond doubt that oil is found at these very great depths. Now, in the next century, I have every confidence in asserting that no matter whether it be a question of oil prospecting or prospecting for other kinds of mineral wealth there will be bores reaching a depth of between nine and ten miles.

'Boring to such great depths will probably be carried out by turbo- or electro-boring machines, or else there will be equipment incorporating entirely new principles, such as high-frequency current, or super-sound through guided explosions.

'A word now as to how exhaustively an oil-bed can be drained of its contents. A laboratory experiment that has been engaged in with a view to solving the question is this: sand is mixed with oil, the proportion of the latter being five per cent of the former, by weight. The mixture is placed in a vessel into which high-pressure gas is pumped. This gas dissolves the oil, which passes into a chamber where decreased pressure is maintained, and settles; so you see in future there will be an incomparably more effective way of tapping an oil-bearing seam: not only will it be possible to maintain pressure in the seam – which, by the way, is already practised by the method of pumping in water to flood round the seam's perimeter – but there will also be the means of introducing a *variable* pressure, so that, by increasing it, the volatile hydrocarbons are turned to liquid, or conversely, by lowering it, they resume their gaseous state. What is more, a means will probably be found for effecting changes in the seam's temperature. So then, we shall at last have mastered the problem to the extent of extracting a good ninety-five per cent or ninety-seven per cent of the oil, instead of that miserable fifty per cent.

'Then there's another very important problem which, I daresay, will be tackled sooner or later: we are still in the dark about the long underground migrations that are suspected of oil in certain cases – scientists think it is capable of travelling long distances from seam to seam, so that the place where it is tapped could even be hundreds of miles from its place of origin; anyhow, the whole why and wherefore underlying the matter will doubtlessly be put to the closest scrutiny; and the knowledge thus gained could well be put to great practical use: it might be possible, say, to divert a stream of oil over a given distance, in such a way that it could be brought to the surface at some much more convenient location. So eventually, maybe, it will not be so much a question of boring for oil at a place where its existence is suspected, but rather of diverting underground streams of oil to bores made in advance at selected spots.

'A dream – a fantasy, all this? Perhaps so! But science has turned into reality within half a century some very much bolder dreams than these! Look at wireless, for instance – it is not yet even three-quarters of a century old, but through it has been realized not only man's yearning for a means of long distance intercommunication – as practised by Morse Code – but it is also an agency for broadcasting music, all sorts of other sounds, instructions to shipping and aircraft – to mention only a tiny handful of its uses – and of course, through its development along lines of television, we now have pictorial broadcasting as well. At the present rate of progress, a fifty-year interval between an idea's initial conception and its materialization may be considered a long one.

'What will be the shape of things in the oil industry in the next century? It is not, perhaps, quite so easy to visualize this as one might think.

'Firstly, prospecting methods will be perfected to the point where a geologist will be able to mark on the map the exact position and outline of a new oil-field without any necessity for preliminary boring – the first bores, in fact, will be those for the industrial exploitation of the site.

'All derricks will be fully automatic; and such dozens and dozens of them as may be found on one site will be under remote control from a central point, where a single operator on duty will attend to every one. This operator will have before him not only an ordinary surface plan of the whole site, but also a vertical section of the soil beneath. When a bore is being made, this diagram will enable him to watch the progress of the drill through the strata. If necessary, he will issue an instruction to divert the drill's course slightly, and then he will have the satisfaction of seeing it making a dead set towards the oil treasure chest. The piercing of a seam will not result in the familiar volcanic phenomenon of flame and smoke from burning oil-gas – no such waste of valuable fuel will be tolerated, and equipment of a special type will ensure that none escapes at all. A certain proportion of the gas will be burnt for obtaining soot – a product of great value in quite a number of different industries. Not even the heat generated as the gas burns will be wasted: by the use of thermo-elements of semi-conductor material it will be turned into electric current for the oil-field's own domestic needs. Some part of the gas will pass through plastic pipes to join a country-wide gas "grid", which will be analogous to our already familiar electricity "grid".

'Oil will also be pumped into another set of similar pipes which will convey it to the great "main-line" oil pipes leading to refineries; at this most vital operation, the man at the control-centre will be called upon to exercise his skill to the very utmost, for this is the juncture where he regulates the conditions of atmosphere and temperature in a seam that may be many thousands of feet below the surface. In doing this, it will be his aim to have the oil-seam eventually drained of practically every single drop. The reactions of mineral oil to atmosphere and temperature vary a great deal from one oil-field to another; therefore, to bring the job to a successful conclusion, the operator would have to be thoroughly conversant with all the peculiarities of the oil in question, and, of course, it would be essential for him to know its exact chemical composition.'

Our car drove along the magnificent Lenin Way. To the left towered the huge white building of a hospital among the trees and to the right a severe majestic house designed by the architect, I. V. Joltowski. Our wheels hardly made a sound on the macadam which gleamed like a mirror after a spring shower.

The macadam owes its origin to oil. Another derivative of oil is the synthetic rubber used for the tyres of our car. The product of oil distillation, in other words petrol, explodes with a mixture of air in the cylinders of the engine, allowing us to speed along our roads. The car could not run without another oil product – lubricating oil. The plastic steering wheel, the blue paint which reflects the sun, the rubber mats, the insulation on the electric wiring . . . it is almost impossible to enumerate all the objects whose origin lies in oil.

If we pay due attention, no matter where we may be – in a house, a club, or on the street we find a host of near and distant relatives of oil. The value of this black gold is incalculable in modern life. The two scientists have revealed to us only a few secrets of the future of oil.

CHAPTER 6

Water Power

PROFESSOR Alexandrov Vasilievich Vinter – his lean face, goatee beard, and penetrating expression are well-known from his portraits – tapped his fountain pen on the green-baize table and looked thoughtful. We knew that he was thinking of the past and conjuring up old memories.

'After the October Revolution,' Vinter told us, 'the young Soviet Republic inherited a very backward state of affairs in industry from the Tsarist regime. Things were particularly bad in the field of electric power. Under the old order not a single important hydro-electric station had been built, although our country, more than any other, was ideal for harnessing water power.

'As soon as the government was in power, Vladimir Ilyich Lenin declared that socialism could be built up in our country on one condition alone: the reconstruction of all industry, agriculture, and transport on the basis of electric power. I remember that Lenin's classic formula defining communism was: government by the Soviets plus electrification of the whole land.

'As early as 1918 work began on the hydro-electric stations of Volkovsk and Nijnie-Svirsk. The latter project was abandoned and work continued only at Volkovsk. In 1926 this station began to function and in those days its power was considered colossal – 56,000 kilowatts.

'In February 1920, at Lenin's suggestion, a commission was set up under the name of GOELRO for electrification in Russia. This commission was to work out a plan for electrification and reconstruction of the economy of our country covering the next ten or fifteen years. It completed its task towards the end of 1920. The plan was discussed at the Eighth Soviet Congress in December 1920 and approved. It was immediately put into effect.

'The GOELRO plan envisaged the construction during the next ten to fifteen years of thirty electric power stations, including ten hydro-electric stations, the remainder being thermal ones, giving a total power of 1½ million kilowatts. Moreover, the existing stations were to be rebuilt to give a power of 250,000 kilowatts. This plan was approved in 1920 in the course of which only 500,000 kilowatt-hours were produced all told!

'The GOELRO plan was completed in full after ten years, and after fifteen years the production of power was tripled.

'In February 1927 the Soviet government decided to build a huge hydro-electric station on the Dnieper in the vicinity of Horitza Island, on that section of the river known as the "Wolf's Throat". The general plan of this scheme was the work of Professor Alexandrov. It entailed the building of a dam and a hydro-electric station with thirteen units each developing 30,000 kilowatts. The total power of the station, therefore, would amount to 390,000 kilowatts. Shortly after building started, however, the technical part of the plan was revised. More powerful machines, each developing 62,000 kilowatts, were chosen and the number of units was reduced to nine. This meant that the station would have a cheaper, more compact, and more powerful plant installation, its total output being defined at a nominal 557,000 kilowatts. This station, built in the extremely short time of five years, was the largest in Europe, and it continued to hold first place until the building of the new station at Kuibyschev.'

Through the window we could see the green beauty of spring. It was the year 1957. Before us sat a man, who, one such pleasant spring day of 1901, was suddenly torn away from his studies at the age of twenty-three, and after a four-month term of imprisonment, banished to Baku. He was already a revolutionary – a revolutionary in politics and in science. During his exile at Baku he assisted in the building of the first steam turbines in Russia which were coupled to generators developing 20,000 volts – a most impressive figure for those days!

As one who now ranked as a 'politically unreliable' in the view of the Tsarist authorities, Vinter was not able to return from exile and resume his studies until 1907; then, having completed them in 1912, he became assistant engineer and later, chief engineer of the first electric power station in Russia to run on peat.

The October Revolution opened vast horizons, making possible everything which had hitherto been considered a dream. Vinter became one of the creators of Soviet power production. He was engineer-in-chief at the construction of the Shatursk and Dneprostroi power stations. His services received the fullest recognition: in 1932 he was elected a full member of the Academy of Science.

What interesting changes this man has witnessed during his lifetime! Naturally, in a short interview he could not impart to us a fraction of the experience he had gained. But he seemed to have read our thoughts for he became even more concise in his explanations.

'I shall not attempt to enumerate all the electric power stations that were built in the intervening period between then and now,' he continued. 'But I should like to draw your attention to something else: after a further two or three five-year plans, there will not be a single exploitable river in the European part of our country that will remain unexploited for power purposes.

'By 1960 we plan to produce up to 320 milliard kilowatts per annum in all our power stations. This means that in a single day we shall have available double the power produced during the whole of 1920.

'But will hydro-electric development stop short here? – can it not go further? Most certainly it can! Because the major part of our country's wealth lies beyond the Urals, in Siberia. To harness the great rivers of Siberia in the service of our national economy – there can be no question of completing that task in a single five-year plan – more likely, it will take until the turn of the century. When it is done, the great Siberian rivers – the Angara, Lena, and Yenisei, and others, will be turned into chains of huge reservoirs or landlocked seas, enclosed by the dams of hydro-electric stations – just as the Volga is now, in fact.

'We have already started to exploit these rivers. It is common knowledge that we are building the first power stations on the large Siberian rivers.

'On the Angara alone, the cascades of the power stations will have a total potential of about nine million kilowatts, giving an annual production of over sixty milliard kilowatt-hours. There will be similar schemes on the Yenisei, where work has started on the Krasnoyarsk hydro-electric station, the capacity of which will be four million kilowatts, and it will, I think, be on the same river that we shall eventually have one of the world's greatest power stations with a capacity exceeding that of the Krasnoyarsk station by two million kilowatts.

'The output of a vast amount of extraordinarily cheap electricity on the Siberian rivers will inevitably be followed by the setting up there, on the spot, of industries that are particularly heavy on the consumption of electricity, such as the manufacture of aluminium, rubber, magnesium, high-quality steel, etc.; and there can be no doubt whatsoever that in the course of the next few decades the main seat of industry will increasingly become Siberia, with its great natural wealth.

'Will there be any possibility of further development of power in our country once these goals have been reached? Yes, certainly. Because electric power represents the wealth of our land and cannot fail to improve our living conditions, which are those of socialist development.

'I am quite sure that by 1970 we shall be producing more than 1,000 milliard kilowatt-hours, and we should soon overtake the United States – at the moment, we lag considerably behind them. Towards the turn of the century our production of electric power should reach the figure of twelve to fifteen thousand milliard kilowatt-hours per year.

'This is the path electrification has taken in our country – from the tiny lamp which illuminated Lenin's study in the days when the GOELRO plan was born, to the giant power stations which are already or will soon be in service. Such are our thoughts on the future.

'When I recall my meetings with Vladimir Ilyich, I think that he would be proud of our achievements and of our tremendous prospects.'

CHAPTER 7

The Power Balance of A.D. 2007

PROFESSOR Valerij Ivanovitch Popkov, of the Russian Academy of Science, met us in his study and did not once sit down during the interview. Energetic and dynamic, he seemed unable to relax.

Popkov belongs to the younger generation of Soviet scientists. In 1930, when Vinter was already famous as the designer of the largest power station in Europe, namely Dneprostroi, Popkov had barely finished his studies at the Moscow Institute of Electrotechnics. He did not have to emigrate to America to find work like Bardin, nor was he exiled and prevented from studying like Vinter. His creative talents developed and thrived in a socialist society.

Popkov's main works concern highly technical questions: high-voltage technique, high-tension electrical discharge in gas, long-distance electric transmission; and the study of the physical processes in electro-filters. A terse and dry recitation that may be, but the implications behind it are hundreds of experiments, calculations, and researches which have contributed to the building of giant dams on the Volga and to the creation of electric power lines unprecedented in their length and the tension they carry, and which will be of invaluable service to the future development of electrification.

'The power position in the twenty-first century,' said Popkov, 'will probably be very different from what it is today, just as our achievements appear miraculous compared with those at the end of the nineteenth century; and the tempo of technical progress has become hectic indeed. The inestimable value of having a liberal supply of power at hand, has now been brought home to people everywhere. I am sure that the yearly figure of the electric power production suggested by Alexander Vasilievich, twelve to fifteen thousand milliard kilowatt-hours, will be achieved during the present century. Towards the beginning of the next century, I think that we shall be producing about 20,000 milliard kilowatt-hours per year.

'You ask me from what sources of energy these figures will be obtained. The likelihood is that the thermal power station, instead of contributing as much as eighty-five per cent of the country's electric power, will supply only about one half of it. But the thermal generating station will be thus reduced in status as a provider of power, not only by the hydro-electric competitor, together with analogous but more recent expedients in using the so-called "perpetual" sources of power – taken altogether, they, in my opinion, will not be able to supply more than some ten to fifteen per cent. Far more serious competitors will be the atomic power stations. In the year 2007 these will probably produce not less than forty per cent of all electric power.

'Will electric power stations be subjected to any fundamental changes? I think that hydro-electric stations will remain virtually unchanged, efficiency being relatively high; but there should certainly be some radical changes where thermal and atomic power are concerned.

'Let us start with the thermal power stations. What is their main defect? It is their low efficiency. It is a fact that only one-third of the potential energy contained in the coal consumed at those stations is transformed into electric power. One effectual means that is now employed for heightening their efficiency is to increase the pressure and temperature of the steam. In a 150,000 kilowatt turbo-generator, the steam works at a pressure of 170 atmospheres and at a temperature of 550° C. Can you imagine such steam? Its temperature is that required for white heat in metals. Experts in the thermotechnical field have been helped by recent metallurgical achievements in their attempts to effect further increase up to 300,000 or 500,000 kilowatts in the output of a single turbo-generator unit (inclusive of boiler); for this, parallel increases of pressure and temperature would be required, up to 300 atmospheres and 650° C., respectively. This would raise the efficiency to about forty per cent. But for any improvement beyond that a complete and radical departure in the matter of energy conversion would be essential. First and foremost, in effecting such changes, must come the exclusion of the heat or steam stage – that energy stage consisting of the disorderly movement of molecules – from the "chain" of power conversion that is needed to produce electricity. I am sure, in fact, that future power technique will repudiate that protracted "chain" of energy transformation that we have today, for just think of it: the coal's chemical energy must be turned into the thermal energy of steam, which, in its turn, is converted into kinetic or mechanical energy as it turns the rotor of the turbo-generator; then finally, from the mechanical energy there emerges electric energy.

'The atomic power stations that we know at the present time are nothing more or less than the same old thermal ones, except that the atomic reactor substitutes the steam boiler. But what is more, the contemporary atomic station emulates the thermal one, not only by functioning on the same principle, but also by having the same low efficiency – less than seventeen per cent, in fact, in the case of the world's first atomic station.

'I believe that the second half of the twentieth century will be noted for two revolutionary discoveries: (1) the discovery of a simple and economical method of direct transformation of chemical energy of coal into electric power; (2) the transformation of atomic energy into electric power.

'Such transformations are possible. Remember that today there already exist – even if only in laboratories – semiconductor elements, in which the power of nuclear fission is transformed directly into electric power.

'Theoretically, it is perfectly possible, also, to convert directly into electricity the chemical energy contained in ordinary, non-nuclear fuels, thus cutting out the thermal stage. Obtaining electricity by these means really bears quite strong comparison to the way it is obtained when we switch on a simple pocket torch! But between theory and practical realization on a large scale lies a long and gruelling, though exceedingly interesting, road of research and investigation.

'I envisage the thermal and atomic power stations of the future to be without the familiar interior of spacious machine-shops – I would conceive them rather as something more in the nature of an enclosed reactor, into which fuel would be gradually served, while there flows from it a permanent output of electric current. In the matter of efficiency, these stations will be just as satisfactory as the hydro-electric ones.'

Popkov went over to a large map of the U.S.S.R. which took up the whole of one wall in the room; on the map, lines of pointer arrows swept over mountain and plain.

'I want to dwell for a moment on the technical problem of creating a single high-power grid, to which all the power stations of the country will be linked, so that their power will be used by every consumer. This grid will cover the whole of the U.S.S.R. In the East it will join up with the Chinese network, and in the West with the networks of the Peoples' democracies.

'Today the maximum distance of electric power transmission does not exceed some 625 miles. In the grid system just mentioned, considerably greater transmission distances will be possible. To achieve this, tension will also have to be increased. Today we are impressed by a transmission line such as that from Kuibyshev to Moscow, which carries 400,000 volts A.C. But in the next century, D.C. transmission at 1½ to 2 million volts will probably be quite normal. For the longest lines, tension will be even higher.

'What will be the aspect of such lines? Indubitably we shall have to solve the problem of insulation anew; it will be necessary to find a means of making all electrical materials used, and above all, the atmosphere surrounding them, stand up to such ultra-high tension. We can safely say that in addition to overhead wires for long transmissions, cables will be run underground. There will be transmission lines for both alternating and direct current.

'I have devoted myself to the problems of high tension, and this is my specialized field. For me, at the present time, the problem of tensions extending to several million volts is unknown territory, a field which has not yet been explored. But for a scientist of the next century dealing with this branch of science, my present researches will be problems already solved. In his laboratory he will obtain and investigate million-volt tensions.'

CHAPTER 8

Farhad's Hammer – Modern Version

Do you recall the charming eastern legend of the popular hero, Farhad, and his beautiful Shirin? They loved each other deeply and with great fidelity. But Fate separated them, placing insuperable obstacles in their path. Farhad had to pierce high, rocky mountains with his hammer, and only after years of such hard labour was he united with his loved one. In his heart dwelt one supreme aim, and he begrudged neither his youth, his fine physique, nor, in fact, the best part of a lifetime in order to realize it.

Farhad has been immortalized. His legend is applicable to the fate of humanity reaching out for its goal over the mountains of time and toil. Farhad was inspired by the marvellous image of Shirin. Our own inspiration is the enlightened age of socialism, the age of peace, happiness, and creative work. What a wealth of poetry and deep significance there is in that old legend!

We were the guests of Professor Georgi Yosifovitch Pokrovsky. He is no philologist, no avid student of folk lore; he is one of the greatest specialists in the field of explosives. At the start of our conversation, however, he evoked the marvellous legend so vividly that he might have been a poet. Incidentally, we knew that the professor had written poetry, the theme of which is the romance of work and science. He illustrates many of his articles himself. He is a talented landscape painter and plays his own compositions at family musical parties. It was difficult to believe that this man, so full of zest for life and beauty, dealt with materials of such death-telling, destructive power.

He seemed to have divined our thought.

'For centuries,' he began, 'explosives have been a destructive agency. At one time scientists had only one object in mind: to increase the power of the explosion. In the twentieth century science has made such giant strides that explosion possibilities are practically unlimited. Today scientists declare quite openly that the use of ultra-powerful explosives for military purposes (for example nuclear weapons) could threaten not only the existence of individual cities and states, but the whole of mankind, the whole world. Military technique in this field has reached a limit which can only be exceeded by madmen. But I hope that this will never happen; and it would be unthinkable to contemplate using such terrible power for any purposes other than peaceful, constructive ones.

'Let us look a little ahead to the relatively near future when Siberia will be covered by a network of highways and railways running from West to East, when the shortest route of all from Western Europe to Pekin will stretch across Soviet Central Asia. In the next few decades, friendly and ever closer relations between the peoples of Asia, increasingly felt economic considerations, will confront the inhabitants of our hemisphere with the problem of crossing the Himalayas and the whole mountain chain which separates Central from Southern Asia. It will be realized in due course that North-to-South communication is of even greater importance in peacetime economy than are the existing links running West-to-East; thus, a weapon of some kind will be sought for piercing the mountain wall that separates North from South. That weapon will be the power of explosion.

'Here's what happened in China during the construction of the railway from Baotzin to Chendu: in order to straighten out the course of a wayward river, the Chinese engineers, helped by Soviet experts, dealt in forthright fashion with a would-be obstructing mountain by blasting a trough clean through it. The river was diverted into this channel; then came a few more such guided explosions, and a further cut was made through the mountain. The result then revealed, believe it or not, was that alongside the river there appeared a couple of quite neat, ready-made railway embankments! Their course, their height, even their form, had been calculated in advance....

'Tasks and deeds which could be a lifetime's dedication for heroes of fable and legend, are now often done in weeks – even hours. On the last day of 1956, China suddenly acquired a new source of iron ore, at a point somewhat north of Lanchow. By exploding 9,200 tons of ammonial nitrate brought to the spot in over 500 railway wagons, the buried ore was laid bare in one stroke, a full year's work being thus accomplished in a matter of seconds. This unprecedented explosion was such a complicated, delicate, and at the same time gigantic operation, that nobody in capitalist countries has ever even attempted anything like it.

'Now these days, the very same raw material which is widely used in agricultural fertilizers is also used for explosives. Might we therefore anticipate that an increasingly wide peacetime employment of explosives would mean starving crops of their nourishment?

'Nothing of the sort will be the case at all: into the customary drill hole, a cylinder about eight inches in diameter will be inserted, this small object being a thermonuclear charge which will perform the task of tens of thousands, or even hundreds of thousands of ordinary explosives. The underground storage space required for that quantity of explosives would, roughly speaking, be the equivalent of twenty eight-storey houses! So it can be imagined how immeasurably matters would be speeded up and simplified by the nuclear alternative.

'Look at a diagram of one of these subterranean thermonuclear bombs; what has become of the small atom bomb that serves as a fuse and percussion cap to the hydrogen bomb? In its place is an amazing electrical device – a cumulative dicharger. In one moment, functioning in the tiniest space, it can create a concentration of energy and temperature sufficient to set up and develop thermo-nuclear reaction.

'Not for nothing was it that the Academician Artsimovitch, who was the pioneer of these fuses, made use of such a phenomenon as accumulation. Not even the boldest spirits, a short time ago, could envisage the astonishing results which would be obtained by scientists through the use of cumulative effect.

'A concave mirror collects together the sun's rays into one pin-point. This is accumulation. In the concave mirror's focal point, wood can be ignited and metal smelted.

'Now, make such a mirror out of a metal capable of throwing out an electric charge of tremendous force. The whole force of the explosion, on the concave side of the mirror, will be aimed at one point: the focus. This is the cumulative, directed, concentrated electric explosion; its force is terrific. During the Second World War, cumulative shells, functioning on simple explosives would pierce the armour of tanks, which was occasionally several times thicker than the shell itself; but with the electric explosion, an even more intensive concentration of energy is possible; and it is, in fact, the principle employed for the fuses of our non-destructive, creative hydrogen bomb.

'The germs of future technique abound in many of the present-day experiments of scientists: it might be questioned whether anything very exceptional would happen by exploding a fuse in the form of a cylinder, but the result is truly amazing.'

Georgi Yosifovitch picked up a large, round pencil from the table. 'If this pencil', he said, 'were made of explosive substance, the force of the explosion would be directed not only outwards, but, as a result of cumulative force, inwards towards the axis of the cylinder, on the lead inside the pencil. The pressure inside the axis rises, increasing for the space of a brief moment to colossal proportions. From the "pencil" there comes a flow of gas at either end, which flow follows the course of the "lead", or axis, before issuing. If the whole cylinder of gas were made to explode at once, this gas would disperse at the very highest speed known – super-cosmic speed of 56¼ miles per second – twice as fast as the earth travels in space and eight times faster than the rocket fired from the earth on an interplanetary voyage. Personally, I think that such speeds will become practical realities before the end of this century.'

We made our way together to the laboratory.

'I am sure you will not be able to guess how this tube was made,' said Professor Pokrovsky, inviting us over to a table on which stood a kind of steel cylinder not unlike the barrel of a small calibre revolver with a very diminutive bore. 'This is martensite, a steel with a high content of carbon, and so hard that a file will simply skim away from it. But before the explosion, it was only soft iron.'

The professor was bent upon satisfying our curiosity to the full, and what he showed us was astonishing. We then went over to the 'Sixty October Years' smelting works. It is very difficult to forge details out of wolfram, molybdenum, and other hard, refractory metals. They are scarcely amenable to the rolling mill; by orthodox processes one could not make such a thing as a tube out of them, for instance. But without this small component, neither the heavy atomic plant of power stations, nor lightweight atomic aircraft engines, could function. However, the works we visited had overcome all difficulties, and one of the shops was given over to pressing and moulding these tubes by means of explosions.

The whole department was purring rhythmically when we entered. A running belt introduced a molten tube made of explosive substance into a concrete chamber. Inside, it was covered with a thin layer of the finest powdered wolfram. The chamber is closed tight. A button is pressed, then – explosion! The explosion causes the wolfram powder to pound itself hard into the tube's axis line, which latter, like a spring, first of all inertly contracts, then rebounds out wide. This results in a through, end-to-end hole being made in the cylinder, as in a pencil from which the lead is extracted. The tube may now be cooled. This quite formidable machine, with all its complex gas jets and tubes, is tended by one youth; now and again, we noticed, he would vary the strength of charge and the explosion range – for after all, he turns out these tubes to order – in varying sizes. The tubes, still hot and emitting streaks of vapour, were run off on a conveyor-belt to the finished products store.

'These are only a few examples of the application of explosions in future science,' said the professor. 'In the future, there is no doubt that in all sorts of different cases, increasingly frequent recourse will be had to the explosion, which is an amazing, and so far, largely uninvestigated method of effecting instantaneous conversion of energy.'

CHAPTER 9

In the Cause of Life and Plenty

IN conversation with us one day, A. N. Nessmayanov said: 'Whatever you do, don't omit to include some doctors and surgeons amongst the people you are going to see; in their sphere, prospects for the next century loom large indeed; by then, I believe, all the ailments that torment the human race today will have been conquered. Medicine in our days has made terrific progress. A short while ago, pneumonia was a serious, protracted, and often fatal illness. Today, a few penicillin injections will soon have the invalid back at work. The question of totally exterminating tuberculosis is now spoken of seriously as a practical possibility. It is true that cancer, mental derangements, and vascular heart disease remain unconquered. But I have no doubt that none of these diseases will be more dangerous than pneumonia is today. So how on earth will doctors employ their time?

'I think that they would be bored if they confined themselves to hygiene and like matters. But I can think of one very great task that tomorrow's doctors will probably get down to: the further perfection of the human organism – a task that will never really be finished. Even at the present time we are not total strangers to any such science, for after all, what is the aim pursued by physical culture? But in future times, it will assume new and various forms, and its practice will be on a scale hitherto unheard of – all totally different from anything we have so far implied by "physical culture". My own view is that it matters little whether a man is capable or not, say, of lifting some specified weight with his left hand, but what is surely a thousand times more important is that he should be healthy and constitutionally strong – it is not muscular development that we need concern ourselves with, but with improvements of the most widely varying kind.

'Look, for instance, at what scope is offered in this respect by the present limitations in our rate of reading – one page per minute. Does that not seem to you far too slow as an average speed for reading a novel? *The Life of Klim Samghin* is a wonderful book, but it takes at least twenty-four hours to read! Today we have to take notes at lectures or discussions, to compile a card-index for consulting scientific literature, since experience tells us that to rely solely on the memory is a risky business.

'All this wastes time which could be better spent on creative work. Undoubtedly, the perfection and intensification of all human activity that involves the higher nervous system will be one of the most important tasks of medicine in the future. The man who solves or points the way to the solution of this problem will be so honoured by his grateful fellow human beings that every capital in the world will contain a monument to him.'

Nessmayanov said all this to us with a smile and more or less in parenthesis; its importance, however, in determining the final shape of this volume was considerable: having duly weighed his words, we were convinced that the amount of attention that we had proposed devoting to biological and medical matters was insufficient, and we revised our plans accordingly.

The whole progress of science may fitly be likened to an unremitting, eternal assault along a straggling, many-sectored front, beyond which lies the sphere of the unknown. Taking the comparison a little further, one may find here such familiar phenomena of warfare as deep inroads into enemy territory developed from several directions, and in which, far up in front at the spearhead of attack, the most widely diverse scientific detachments may be found rubbing shoulders. One may also observe sudden 'blitzkrieg' assaults on some particularly stubborn bastions, while others are besieged over a period of years. Inevitably, of course, there are occasional retreats, such as when some seemingly triumphant new theory is crushingly invalidated by hard facts.

At points where the front has been penetrated, the advance is constant, and mutual support between individual sectors exists here too, just as on the battle-front: success in one sector of the scientific front may facilitate the progress of neighbouring, or perhaps quite remote sectors.

To be first in world science means to be first in those points of the front where a break-through has either just taken place, or is imminent. Scientific triumphs of recent years have been conspicuous, above all, in the atomic field; and it is seen how this great atomic 'break-through' has set in motion forward movements of numerous other – and one would have thought – quite remote sectors of the general scientific front: on the biological sectors a great gain has come about, in so far as a certain method of 'marking' atoms has enabled biologists to widen their knowledge of metabolism in vegetable organisms. In the field of medicine, the secrets of malignant tumours have become less forbidding since they have been studied with the help of radioactive isotopes. Even history has not remained unaffected: through analysis of isotopes, scientists have been able to tell us exactly when the chariots of the Egyptian Pharaohs and the ships of Vikings were constructed. So far-reaching have been the repercussions from this 'break-through' that a full assessment of them is well-nigh impossible; and we may be sure, too, that as yet by no means all the repercussions have been manifested. Apart from this matter of consequences, the discovery itself is, of course, unceasingly being subjected to further research and elaboration. The new knowledge gained, the new laws discovered, can only be of untold value in the approach to thousands of other problems.

Another great triumph on this scientific front is the advent of plastics, which are continually ousting wood and stone from building construction, and they even challenge the supremacy of metal in mechanical construction. Plastics have now invaded practically every conceivable industrial and domestic sphere.

For electricity, a very outstanding landmark is the introduction of semi-conductors.

But perhaps the most truly epoch-making 'break-through' of all has been the launching of artificial satellites, the first celestial bodies to be devised by human beings. To what extent will this penetration of space react on science in general? – how much significance, for instance, could an acquaintance with the vegetation of Mars have for biology – or even agriculture? How might metallurgists and geologists gain from a knowledge of the minerals on the Moon or Mercury? We can only say that the number of different sciences that are bound to be profoundly affected by all this will be large indeed.

A highly complicated and responsible charge on the scientific front will be to determine which sectors are to be singled out for maximum assault, and to organize concentrations of scientific forces thereon. The U.S.S.R. Academy of Science is greatly preoccupied with this matter.

Amongst the numerous scientists we have spoken to, we have found invariable agreement to the effect that, in the near future, on no sector of the front will there be seen bolder penetration into the unknown than on the biological sector.

How wonderful and astonishing may be the secrets soon to be unfolded by the great science of biology – the science of life itself!

Just as the first half of the twentieth century has been characterized by the brilliant achievements of the nuclear physicist in his mastery of the atomic cell, so may its second half become historic by virtue of the biologist's great victory in wresting from Nature the secrets of the living cell. Physicists have learned how to transform one chemical element into another; biologists will learn how to create albuminous molecules, live substance.

Not only biologists, but many scientists of other and seemingly quite far removed realms are now included in the general line-up for the great assault upon Nature's secrets. Simultaneously with the biologist's analytical approach to the secrets of the cell, the nucleus, the gene, and the albuminous molecule, an approach is being made from a different angle by the organic chemist, whose attack upon these secrets consists in the synthesis of more and more composite molecules. While psychologists are grappling with the mysteries of human thought and behaviour by their intensive study of innate and artificial reflex systems, experts in the electronic sphere are bringing out apparatus possessed of faculties for logical action and memorizing in just such a way as if they did, in fact, have those innate and artificial reflexes of human beings.

The methods and successes of other branches of science enrich biology and accelerate its development. It is beyond doubt that biology, taken in the widest sense of the word, is one of the front-line sectors which in the next fifty years will forge ahead in a revolutionary manner, winning brilliant victories.

We now propose to record the interviews we had with some of the outstanding commanders on this sector of the front.

CHAPTER 10

Biology Will Become an Exact Science

'WE know from history that each era of scientific and technical progress is characterized by the great prominence of some one particular branch of human knowledge: we know that the age of steam was followed by that of electricity; the phenomenal progress of chemistry is almost recent in our memory; and at the present time the triumphal march of nuclear physics dominates the scene. Which science will be most to the fore as we enter the next century?

'It is my conviction,' said V. A. Engelhardt, Principal of the Department of Biology of the Academy of Science, 'that by then the leading position will belong to physiochemical biology.

'The world contains no substance the structure of which cannot be fully formulated by analytical chemistry. Synthetic chemistry enriches nature with new substances, outside the natural order, with predetermined properties. Physics has penetrated into the secrets of the atom, revealing new sources of inexhaustible energy.

'In their rapid advance, the exact sciences have devoted the greater part of their attention to inert matter. A great event is taking place right before us now: biology, too, i.e. the study of the living world, is becoming an exact science to an ever increasing extent. This results from an ever wider application in the study of living organisms, of the research methods characteristic of the exact sciences, in other words, of physics, chemistry, and mathematics.

'The great dream of countless generations has been the prolonging of human life. Even if progress is not as fast as we should like, we are well on our way to this goal: within the lifetime of one generation the average expectancy of life has gone up by at least twenty years, and this has been due to the almost total conquest of some of the chief bacterial diseases, notably croup, typhoid, malaria, and tuberculosis. Another very great triumph that we are entitled to expect of science in the near future is the laying bare of the true nature of cancer – what we have to know there exactly is: in what peculiar way does the course and general behaviour of the chemical processes in the unhealthy tissue – the tumour – in what peculiar way does that regime differ from the processes in the healthy and unaffected tissues; once that can be established, the search for an effective means of combating this terrible scourge will become a practical proposition.

'Scientists can already see this victory within their reach. Even the most cautious specialists speak of a period of twenty years. If their prophecies are fulfilled, before the half century under discussion has elapsed humanity will begin to forget the threat of cancer, just as it is now forgetting the threats of smallpox and hydrophobia.

'It is hard to say who will win this ultimate victory; chemists with their drugs or physicists with radiotherapy. It will, in all probability, be won by the combined efforts of the two.

'Now, suppose that chemists discovered certain substances which on being introduced to the tumour, could be retained by its tissues, as if by a filter; suppose, too, that the tumour containing an accumulation of such substance is subjected to neutron radiation, which for the healthy unaffected tissues is harmless, the accumulation in the tumour will then become radioactive, and the interior radiation thus induced will destroy the tumour, but do no harm at all to the rest of the body.

'The conquest of disease will greatly prolong human life. But we have another interesting possibility: we spend a third of our life in sleep, thereby losing time which could be used to our personal advantage or for society.

'While we sleep, the restoration of the nervous cell tissues takes place, and sleep's own peculiar kind of replenishment and toning up of the whole nervous system is brought into play. The dross of the vitality of the nervous cells, which we might call the toxins of tiredness, are neutralized.

'During the war, certain drugs were brought out – benzedrine and some others – which for periods of varying length would keep mental fatigue at bay and enable one to stay awake two or three times longer than habitually; in these cases, however, sleep would take its revenge and demand considerably more than its usual toll afterwards. Chemists will undoubtedly tackle the whole question of the aforementioned "toxins of tiredness", and having become fully satisfied both as to their composition and their formation, they will either devise a method of neutralizing them through ferments of some kind, or else of binding and "overwhelming" them by some chemically harmless medicinal preparation.

'But one can think of other ways of overcoming tiredness. Let us imagine, for instance, that some type of electric vibrations was discovered which when applied to the head through tiny electrodes would penetrate the brain and speed up the restorative processes which take place there; then these toxins, which normally take some eight hours' sleep to neutralize, would be rendered harmless in one or two hours without any ill effects on the organism. To shorten the hours of sleep thus would be equivalent to adding twenty or thirty years to the life of a human being.

'From the incursion of chemistry and physics into genetics, we are entitled to anticipate remarkable – even astounding – results in the next few decades. The greatest enigma for biologists at the present time is that of heredity. This problem consists in discovering how, in a single microscopic cell, are determined innumerable details of the structure and functioning of all the organs and tissues; and the characteristic properties of the future adult body, and how it is that the embryo may harbour the combined parental traits.

'The old vitalist theories – about the whole organism being presided over by some independent, mysterious, and inexplicable power of life – have long since been consigned to a well-deserved oblivion. In the present century, biologists have been able to give detailed and rational explanations of the general laws of heredity, and now we are well on the way to being able to reveal finally and in terms of chemistry the nature of those substances whereby the parental traits are transmitted to the offspring. The task that will confront biochemists might be said to consist in deciphering the code language, as it were, of atomic and molecular combinations wherein are chemically and physically determined the qualities to be conveyed to the offspring. A difficult task this is, indeed, but it is not, perhaps, over-optimistic to believe that in fifty years' time this "biological code" will be known like some cut and dried mathematical formula.

'From that moment, science will have completely mastered living nature. Through re-arrangement of atoms contained in genes and chromosomes, it will be possible to give plants and animals such advantageous qualities as are deemed necessary, and these they will transmit to their posterity. Even now, we have achieved a certain amount in this direction where the simplest organisms are concerned. I believe that with the aid of "genetic poisons" we shall be able to liquidate, or if you prefer, "re-educate" many kinds of pathogenic microbes. Biologists will render them harmless by bringing about an artificial change.

'Of all these fantasies there is not one without foundation, in the light of successes already achieved today. The tempo of scientific progress increases like an avalanche and it is probable that a scientist of the year 2007 coming across this book in a library will say: "How modest their dreams were in those days!" I am sure that at least some of the ideas we have talked about today will be realized during this century. I am also convinced that many readers of this book – those who are younger than myself – have before them a grand future, which to us now seems almost fantastic, and that it will be they who make many of our dreams come true.'

CHAPTER II

Bloodless Surgery

IT was a marvellous surgical clinic and the day we spent there would furnish the material for a whole book.

The director of the Institute of Experimental Surgery, Mikhail Gerasimovitch Ananiev, who showed us this average clinic of the future, tiptoed over to one of the wards, and opened the door. The patient with a nod invited us to approach, and in a kind of reflex movement his arm reached for a bedside switch to turn off the wireless; then he pressed a button, and the head of the bed rose so that he could talk to us in a semi-upright position. Another remarkable feature of the construction of this bed: from it the recumbent patient could draw the blinds and switch on the light and the electric fan.

In the next room, at a switchboard, sat a woman in overalls. Facing her were about two dozen television screens. Ananiev, observing our surprise, explained: 'The doctor on duty. She keeps her eye on each serious case, and can summon one of the nurses or a specialist whenever necessary. The electric thermometer and pulsometer keep her constantly informed of the sick man's temperature and pulse.'

But all this apparatus seemed simple compared with what we saw in the diagnosis room. 'That is the stethoscope,' said Ananiev, pointing to the leads running from the bare chest of the patient to a loudspeaker on the table.

We looked in vain for the simple instrument with two black tubes which the doctor normally places in his ears.

'It's a radio stethoscope,' he explained.

From the amplifier we could hear strange, gurgling sounds. It was the blood coursing through the living pump – the man's heart – and the doctor listened to each movement of the muscles as a musician listens to the beats of a metronome.

On a wall fixture similar to a Swedish glass cupboard was the word DIAGNOSIS in bright letters. Ananiev asked the diagnosticians, 'Switch on the calculating apparatus, please.'

His colleague placed the patient on a bed in a niche moulded to the shape of the body and quickly connected up belt and bracelet attachments to the feet, hands, and neck. The indicator lamps flashed and the relay switches began to snap and crackle. The machine 'deliberated' over respiration, blood pressure, and the card giving particulars of blood analysis which had been placed in the machine beforehand. The apparatus also took account of a great number of other details that not even an experienced diagnostician could have considered at one and the same time.

The reply was unexpected. The machine suddenly indicated three diseases with learned Latin names. It seemed to say: 'I have eliminated thousands of variants. The symptoms you indicated are to be found in these three very similar diseases. This is the limit of my capacity. Now you must decide which of these three diseases is the one . . .'

'Switch on the radiolocation,' our guide said to the doctor.

Upon the screen there appeared the outlines of the heart, liver, stomach, and intestines. Accurate to a millimetre, the machine defined all deviations from the normal of the organs' size and position. Translucency with the aid of the radio locator is made possible because each organ possesses a different density.

After a bare ten minutes the doctors knew that the patient was suffering from a very rare disease, the diagnosis of which formerly would have taken a very long time.

But it is one thing to diagnose the complaint and another to cure it.

We asked to be shown the operating theatre. The director accompanied us into an adjoining room.

'You are mistaken, Mikhail Gerasimovitch,' we exclaimed. 'This may be a physiotherapeutic study, but not an operating theatre. Here there is nothing but electrical apparatus. There isn't even an operating table.'

The patient was lying on a bed. Above him, supersonic equipment of some kind hummed gently. No surgeon, no bloody swabs. The director, ignoring our remark, began to explain. From time to time he smiled surreptitiously, knowing the surprise that his words would cause.

'This is an operation on the liver,' he said, 'and you now see our method of removing stones from it.'

We stared open-mouthed and, seeing nothing, exchanged glances and then said jokingly to the doctor: 'Magnificent, Mikhail Gerasimovitch – just think of it – stones being removed from the liver without the surgeon's knife – without touching the patient even! – fantastic surely!'

'Precisely!' he replied. 'In twenty minutes' time all the stones in the liver will be ground down to powder as fine as sand, all of which will be cleared away in a few days by the body's digestive system.'

'But how?' we wanted to ask. Nevertheless we remained silent.

We wanted to ask: 'But the soft tissues, the liver itself, will it not be damaged by this supersonic steam roller?' But we had overlooked the fact that the supersonic vibrations do nothing more drastic to those soft tissues than to warm them up slightly; but to anything hard, such as stone, be it ensconced in the body ever so deeply, those vibrations are deadly – it will be smashed up inevitably.

'Surgery, as you see,' Ananiev went on, 'can cure a man without opening up his body and without crippling him with the knife; and that is just how the ideal operation should be.

'These days, we make very wide use of this power of "inaudible" sound – you'll see how we use it in our dental clinic for drilling teeth: but then, you know, supersonic technique was already in use some seven years ago – not to the same extent as now though. Now let's have a look in another operating room.'

Ananiev told us to exchange our shoes for sterilized rubber slippers and to put on gauze masks. We entered and at last found ourselves in a normal operating theatre. The operating table itself was somewhat different however – more convenient in design and adjustable electrically. The theatre's electric lamps also called for remark: they were of a special kind that has the dual function of providing illumination and killing germs with their rays. Air-conditioning kept the atmosphere beyond reproach, and needless to say the most scrupulous cleanliness was observed.

But why, of all things, should the surgeon have a television screen before him at the operating table?

'This is not ordinary television,' explained the doctor without waiting for our question, 'it is connected to an X-ray apparatus, and, as you know, an X-ray picture can only be directly seen in darkness, but we have got over the difficulty by transferring the picture to a television screen, and by these means the picture is perfectly visible in the bright light of this theatre. Now, in the picture here you can see a sharp hook that has become lodged in this child's stomach after he had swallowed it at play; and so, you see, right from the very start the surgeon can make a bee-line for the hook, and on the screen he can see his own hands and exactly how far he has to go with his scalpel before reaching the objective. But the knife, by the way, is not as a rule required in these cases.'

We were almost speechless – 'dissection without a knife!'

'Yes, remember I've told you we have renounced many of the bad old ways!'

On seeing us whispering together, the surgeon who was to perform the operation silenced us with a stern gesture of admonition:

'We're putting him to sleep now!'

There came a soft hum from the electric anaesthetizer as it lulled the child's brain, and in a minute or two the surgeon announced:

'You can talk loudly now; the patient won't wake up until we switch off the machine. A remarkable apparatus this is,' he continued, '– no unpleasant sensations at all, and just think of the torments people used to go through with chloroform – it's true they were put to sleep, but what about the terrible heavy feeling when they came to afterwards? Then, of course, they had that local anaesthetic – a kind of cocaine blockade that cut off the part in question from the nervous system and made it insensible. This electro-narcosis has evolved from electro-sleep therapy – an idea that was expounded by Pavlov.'

'We can begin now!' motioned the surgeon to the senior sister.

Some students who had arrived to watch the operation went into the auditorium next door, where they would watch it in all its detail on a large television screen built into the wall; while watching the proceedings, they would be given an appropriate lecture. Thus the students would not have to crowd round the surgeon, looking over his shoulder, nor would they be exposed to any harm from the X-rays.

The surgeon took up an object resembling a pencil with a sharp point; a flex attachment ran out from its blunt end over his shoulder.

Had we not seen with our own eyes what then took place, we could never have believed in anything so marvellous:

The surgeon slowly drew this instrument along the stomach skin and in its wake it left a smooth, even cut; but not one drop of blood was to be seen therein – not even when the intestines were exposed to view. . . .

The supersonic 'knife' that the surgeon used actually rendered the whole operation bloodless. Apparently, given the desired frequency, supersonic vibrations can not only cut through tissues, but can also cause blood to coagulate as they do so.

Moreover, before cutting the tissue, the blade anaesthetizes the extremities of the nerves and the cut is therefore painless. This is of great value in cases where deep narcosis is not resorted to; and what is perhaps its most excellent feature of all is that it kills the germs in the wound right on the spot as it furrows through.

So it was with the deepest respect and admiration that we stood watching that wizard of a surgeon wielding that wand of his which could cut without pain, without blood, and antiseptically into the bargain.

As it had been found necessary to open the stomach to extract a hook, we thought that the final phase would be the customary stitching up. But things transpired very differently.

The surgeon gave a terse order: 'Glue please!'

The two raw edges left by the stomach incision lay there side by side. An object much resembling the old wooden mushroom used for darning socks was produced, and daubed along under those edges in order to press well down a glue-saturated strip of transparent film. The stomach wound was simply glued up – nothing more or less!

'You must not think,' said the surgeon, 'that this glueing process has entirely replaced sutures. We have at our disposal in case of need a fine metallic thread of tantalum, which is absolutely harmless to the body, and thread made of fibrin and blood serum, substances very similar to those of the human body. These threads hold the wound together until it is healed. Then the organic substances of which they are made dissolve and disappear without leaving a trace.

'It is possible to drive a nail of rustless steel into a broken femur or shoulder blade; the nail acts as a kind of pivot on which the broken ends of bone will knit together quickly and correctly, and it would need an X-ray to reveal that any foreign body was lodged there. But should a similar peg or "nail" be made of, say, fibrin or blood serum, then by the time the bone has knit – six months at the maximum – there will not be a vestige of any foreign matter, as it will have completely dissolved away.

'You have seen the effect of surgical glue; it is a marvellous method which by the end of the twentieth century will change the whole face of surgery.

'There was a time when glue could only be thought of in terms of its application to metal, glass, porcelain, and so forth; but what we are seeking now is a glue that will do for the body's tissues, nerve ends, blood vessel ends, skin, and broken bones. By the turn of the century, all this will have been mastered, but it is not going to be at all easy to find a glue for the soft tissues.'

In the ward which we now entered lay a solitary patient, and from all appearances his case was one of particular care and concern.

'A bad case of poisoning,' said Ananiev.

'He probably would have died had we not at our disposal artificial kidneys. It's a pity the ones we have are rather on the large side.'

The object to which he referred stood beside the bed, and for that matter it strongly resembled a small bedside cupboard, although it was made of glass; thin tubing connected it to the patient, whose blood flowed through the chemical filters of the apparatus, which cleansed it of urinary sediment and enriched it with the necessary substances; while he was not even aware that his kidneys had been excluded from his body's system.

It was explained to us how serious kidney diseases can be cured by this method, whereby lives are saved by averting self-poisoning from urine. Healthy kidneys from deceased persons can also be grafted on to the living.

We now had the premonition of something out of the ordinary that was to take place.

'Let's go and have a look at the artificial heart – here it is now!' Ananiev pointed through a half-opened door to a cupboard no larger than the average bookcase.

The cupboard was in action. An automatic electric appliance maintained the prescribed regime of 5¼ pints of blood per minute, with the pulse at 80 beats and pressure at 120 units. Should the pressure fall, an increase of blood would be given automatically.

The voice of the surgeon in the next room suddenly broke the silence: 'Nurse, stop the heart – quickly, it's hampering me!'

We all but shuddered – think of the grief of dearest ones when a heart stops beating! – of what Herculean efforts doctors are capable in trying to stave off such a thing! – but now: 'Stop the heart!'

After this heart – a natural, human one, had been duly brought to a standstill, the surgeon calmly drained the blood from it, then proceeded to operate; and while the natural heart, which had been 'switched out', so to speak, lay motionless, the artificial one in the small glazed cupboard kept up with its pumping of blood into the aorta by way of the rubber sleeve connexions.

To use a needle and thread for stitching a wound in a heart, be it only faintly throbbing, is an extremely difficult job; and by the time this stage is reached a surgeon can be tired, with aching hands and arms. So it was then that we were able to appreciate the immense benefit brought by modern surgery's automatic and semi-automatic wound-stitching machines. The surgeon was now holding one of these and inserting it into the ends of blood vessels. At each insertion there would be a little fluttering click as if from the shutter of a camera – no more than a second or two – and the vessel would be made secure. With hand-stitching, a job like this could take half an hour or more. For the heart wound, the surgeon was handed another machine, and here again the stitching only took a matter of seconds. The surgeon then straightened himself up from his bending posture and gave the final order: 'Start up the heart again!'

The 'repaired' heart was filled with blood; this time the latter was diluted with adrenalin, the substance that stimulates the nerves of the cardiac muscles and makes the heart give its first beat.

The heart was now in motion once more and its beats were steadily accelerating. But suddenly the surgeon, who was just on the point of removing his left-hand glove, stood there motionless like one petrified: from the heart there now came a rapid kind of tremor or shuddering sound, and one could no longer distinguish beat from beat – anything from 200 to 300 per minute – so quick that it would be impossible to say just how many! This state is called 'fibrillation', the horrid forerunner of the heart's stoppage once and for all!

But the nurse needed no telling what to do: she handed the surgeon an object that looked vaguely like a rubber stamp with a handle; this, in fact, was an 'electro-defibrillator'. The surgeon applied it to the patient's body, then turned a switch: the tiny, dwarf lightning of an electric charge went clean through the thorax, piercing the heart in its course; the heart thereupon contracted, but a split second afterwards it expanded with gusto, then set about beating with as healthy and steady a rhythm as could be desired. . . .

At this stage, another item of electrical equipment was brought into action: it might be described as a kind of sentinel standing guard over the rhythmic functioning of the heart and lungs, which it automatically regulates when need be.

The operation had lasted only fifteen minutes – not a full hour or so, as we had imagined!

We were told afterwards that the artificial heart had been instrumental in restoring great numbers of bedridden people to active life; also, in numerous serious illnesses, when from one cause or other heart failure threatened, it had been the means whereby the patient could cling on to life during moments of great crisis.

But a word or two about operations in general: it would be a mistake to think that the patient is indifferent in the matter of whether he is to lie on the operating table for five minutes or half an hour. The mechanization of complicated and protracted operations not only speeds up the work of the surgeon, but also makes it safer. Automatic apparatus works just as well in the hands of a virtuoso amongst surgeons as in the hands of an average one.

Ananiev proceeded to tell us about some mid-twentieth-century innovations that have become common practice at the operating table. Apparently the stitching machines have been in use for quite a time. There are also machines that can instantly bind blood vessels and bronchial tubes; these and similar devices can cut the time of an operation down to one-fifth. In the matter of stitching machines, there are special adaptations for each kind of body tissue – pleura, peritoneum, skin, stomach, membrane, and so forth.

We know that broken bones can knit together and that torn or frayed nerves and other tissues become restored with time; so would it be possible, we may appropriately ask, to revivify, say, a leg or arm that had actually been cut off?

'By all means!' exclaimed Ananiev. 'Bring us the limb in question and the owner will be duly rehabilitated with it. For surgery, you see, is entering a rehabilitative phase: suppose you were to injure your knee-cap, for instance, we could remove it and fix you up with a new one – made of plastic and designed to fit perfectly; then with those obstinate malformations that sometimes arise as an aftermath of injury, or in cases of tuberculosis maybe, there should be no difficulty at all in providing replacements for any painful and troublesome joint.

'"God overlooked the question of spare parts for human beings, so take good care of the extremities" – as people would say jokingly in the nineteenth century. But we physicians have created those parts.

'Cases arise where a blood vessel or other organ has a faulty section for some four to six inches of its length: we are now able to extract the faulty section and insert a replacement – a small length of tubing in nylon or some such material.

'But there is another and quite different method where replacements are concerned: some quantity of a deceased person's vessels, organs, etc., are kept preserved and stored in that person's own blood. In refrigeration, the organs can be preserved for a very long time: and indeed, if kept in a vacuum at a temperature of 60° C. below zero, such "spares" can be preserved indefinitely. This method has been adopted in clinics and hospitals for quite a long time. Here, as you see, we are not concerned with replacements made of extraneous materials, but with transplantation of human organs.

'Transplantation,' observed Ananiev, 'is an extremely engaging topic, and one could talk about it for days and nights on end. One interesting experiment, carried out before the twentieth century was fifty years old, was the removal of a dog's kidneys, one of which was then transplanted on the animal's neck, the ureter being brought outside in consequence: the kidney functioned perfectly in its new position, and the dog remained as healthy as if nothing unusual had taken place. Now that was a transplantation in which only one individual – one organism – was concerned; and in such transplantations success is almost a certainty. But when we come to transplantation from one organism to another, the whole picture assumes a very different aspect.

'In 1949 Soviet surgeons extracted the heart from a dog and put another dog's heart in its place. The dog lived eight or ten days or so, then suddenly died. Why? – the problem has long been a sore headache to us.

'However, our technique in this direction has reached a remarkable degree of perfection. Consider, for instance, that intrepid experiment carried out by Surgeon V. P. Demikhov: in 1956 he actually transplanted the head of one puppy on to another puppy's body. For about a week the uniquely composite quadruped pursued a normal existence, seeing, hearing, smelling smells, reaching out for food, and lapping milk; but then it died.

'Why is it that transplanted organs may thus suddenly fail and bring about death? By 1957 all purely technical problems of transplantation were solved; but one great question still remains to be thrashed out: that of the biological compatibility of organisms and tissues.

'A human being will die from a transfusion of blood that is dissimilar to his own; but if given blood belonging to his own blood-group, he will live. There are four such blood-groups; and doctors now have an infallible procedure for the administration of blood transfusions, because they know from A to Z the laws governing blood's biological compatibility – hence the classification of blood into these four groups. But the laws governing the compatibility of the body's organs and tissues are not yet fully known.

'When people get badly burned, they sometimes have the skin of others grafted on to them; but in such cases the grafted skin does not make itself a permanent abode, it merely serves as a kind of framework on which the restoration of the person's own skin may take its course. As soon as there is a growth of new skin beneath the grafted skin, the latter withers away and is thrown off.

'With one exception, tranplantations of organs has not so far succeeded even within the same family, such as between brother and sister, or between parents and children; the exception is a case of a kidney being transplanted from one twin to another. This isolated case has been put to the most intensive study. More and more experiments have been carried out, and gradually the laws of biological compatibility for various organs and tissues are now coming to light. One remarkable experiment, amongst others, is that of Professor Filatov, who has demonstrated that while the cornea, freshly extracted from a deceased person's eye, was not amenable to transplantation at all, it is only necessary to keep that cornea frozen for a certain length of time for all question of its biological incompatibility to be entirely eliminated.

'Complete solution of the biological incompatibility problem is now looming on the near horizon, and once we have it, we shall straightaway deploy the whole arsenal of accumulated experience, where the purely technical aspect of transplantation is concerned. Then we shall be able to extract any organ of a deceased person's body for transplantation; and you know, it is a fact that provided there is no chance defect or injury, an individual organ is capable of serving twice as long as the longest human span of life.

'Looking ahead a little, I can imagine, in some establishment like the Sklifosovsky First Aid Institute, there would be housed a large refrigeration section for preserving the corpses of recently deceased persons; and in them the blood will be kept circulating by artificial means – "living corpses" they would be, in a very literal sense! Thus there would be a store-house that could be drawn upon for any human part or organ required. Personally, I think that in the initial stages, transplantation will be practised, more often than not, with the limbs – and thus the dead will help the living.

'Hullo! – what's up with you, lass?'

Ananiev had risen to his feet and was already busying himself with Tamara, the young stenographer who had closed her eyes and leaned her head on the table.

She had fainted. Absorbed in all this talk, we had completely forgotten that this girl had been listening to it and taking it down in shorthand – this girl who had never before, perhaps, even known the smell of a hospital, let alone any question of blood or corpses! So back down to earth we came and set about reviving her.

Tamara soon felt better and the colour returned to her cheeks; but we kept off 'dangerous' topics and Ananiev spoke of the great human calling of the doctor, comparing his work with that of a conductor of a large orchestra in which many instruments perform complicated musical pieces; the various instruments are not directed by automation but by a man and by a man alone. This comparison was his reply to our question as to whether an operation could ever become purely automatic.

'Of course, all that is mere allegory,' he said, 'but my point is that in becoming more and more adept in complicated, mechanized technique the doctor tends to become a veritable doctor-engineer – a term quite unheard of to date, maybe, but very much of a reality for the next century!'

We thanked Ananiev. He shook us warmly by the hand and then turning to the girl, added: 'You, young lady, should get used to medicine. You are sensitive to human suffering. You might easily become a first-class surgeon!'

CHAPTER 12

The Dawning Age of Plenty

'COULD you tell us', we asked the academician, S. I. Volkovitch, 'how many people our planet could feed? Could there possibly be any limits to the increase of the world's population on this account?'

'There is no limit and there never could be one,' was the prompt reply, and we could see that the question was far from being new to him.

'The potentialities of science in regard to increasing the earth's productivity are unlimited, and remember', he continued, 'that more than fifty years ago Mendeliev estimated that given not only sufficient labour, but also persistent initiative and enterprise, with scientific knowledge as the guiding factor the earth could give sustenance to a population of far more than ten milliard. Mendeliev said this at the very beginning of the twentieth century, when the world's population stood at some 1·6 milliard; the fifty years that have since elapsed have put up that figure by nearly a whole milliard.

'But where can we get the extra nourishment for this ever-increasing humanity?

'An extremely important role, as a reinforcement to Nature's processes for nourishing plant life, may be assigned to various chemical preparations specialized for particular requirements.

'In Central Asia during the Second World War, there was a shortage of nitrogenous and phosphoric fertilizers. As a result of being starved of these fertilizers for a three-year period, the cotton crop was reduced by half; but now, instead of only ten tons or so per hectare, as in those wartime days, the harvest is anything from twenty to twenty-four tons.

'The possibilities opened up by modern chemistry and the chemical industry constitute of themselves the most convincing refutation of the Malthusian theory and of the gloomy diminishing fertility theory, which until recently was even honoured with the status of being a scientific law. Taking the factors contributing to improvements in harvest as mechanical soil-tilling, quality of seed, and use of fertilizers; we shall find, looking at the agricultural experience of a lot of countries, that the picture is much the same: the contribution to improvement of the first and second of these factors amounts to twenty-five per cent from each, while the third factor, that of fertilizers, takes a full fifty per cent of the credit.

'Timiriasev, Prianishnikov, and other scientists maintained that the introduction of organic and mineral fertilizing agents would bring a six- or seven-fold increase in agricultural productivity; but that given a greater area under cultivation, the increase could be twice as big.

'Prianishnikov, in particular, basing his reckoning on the deductions he had made both as to the future growth of our country's population and the probable extent of increased food production, announced in 1925 that for the next 150 years from then Russia need have no qualms about a possible shortage – not even in the extreme event of the country's population being doubled every fifty years. A remarkable forecast indeed! It would seem to anticipate the fruits of such science and technology, that even yet we are far from having attained. However, in the decades that have gone by since those words were spoken great strides have been made by biology and chemistry.

'But reverting a moment to that forecast of Mendeliev: taking account of social progress and statistics that have been subsequently available, the figures he gives could well be doubled – or perhaps even trebled – that is, provided widespread use is made of scientific and technical achievements, twenty to thirty milliard people could find sustenance in this world.

'You can imagine what benefits would accrue if every nation refrained from wasting its wealth on armaments and used it for peaceful, creative ends. I do not believe that the Golden Age lies in the past, but in the future; it will dawn when science, applied to peaceful ends, penetrates and transforms all human cultural and economic activity.

'Chemistry, of course, is bound to loom very large in the future; and in passing, let me mention one very great triumph that stands to its credit in my own sphere of agronomy: the extraction and compounding of nitrogen from the atmosphere, consequent upon which was the advent of the synthetic nitrogenous fertilizer. This achievement crowned years of tireless endeavours on the part of chemists, physicists, and engineers; besides which, the engineering industry spared no pains at all in bringing out most complicated machines made of special steel. Then, of course, one could hardly exaggerate the importance of all our chemical preparations for guarding crops and other plant life against the attentions of harmful weeds, and equally harmful insects and rodents. Of no less importance are those chemical preparations that have the more positive role of regularizing and accelerating growth – of improving fertility; this category, of course, is applicable to animals as well as plant life.

'D.D.T. and other modern pest destroyers are not only infinitely more effectual, but are also safer in handling than those concoctions of sulphur, fluorite, arsenic, and so on that were common formerly.

'We are so accustomed to mineral fertilizers and chemical warfare on crop pests that we are apt to forget that such refinements have not been with us ever since the world began; actually, phosphoric fertilizers were introduced about a hundred years ago; potassium followed about twenty years later; but the synthetic nitrogen variety first appeared only fifty years ago. The present century has seen a solution to all exigencies in regard to fertilizers by the setting up of a mass-production industry in them. Fertilizers are now being turned out in widening variety. The question of micro-elements is now one of the greatest interest and concern to agriculturists, who have made the matter one of infinite experiment and investigation. In plant organisms, the part played by these micro-elements is very much like that played by vitamins and hormones in the human organism; certain micro-elements, moreover, are highly effective against some plant diseases:

boron, for instance, will prevent rot in the core of sugar beet, and it protects flax against bacteriosis. Also, a number of cattle diseases can be guarded against when fodder has certain micro-elements added to it, copper and cobalt being particularly effective here. How great are the results obtained from the tiniest quantities of these elements! It can be confidently anticipated that with fodder thus doctored and with other medicaments besides, cattle will be just as well protected against disease and parasites as are human beings.

'In order to make a flight of fancy into the future, there is no need to indulge in fantastic conjecture; you may notice, for instance, that healthy, robust, and fully grown trees are now to be seen lining the streets of Moscow, whereas formerly, the trees planted there could only be induced to grow with great difficulty, and they often looked sickly and withered. The reason for this remarkable improvement is that the roots are now treated with special matter for accelerating and stimulating growth. If you take only one gramme of certain kinds of organic matter, it will induce rapid development in a plant's roots. These growth stimulators are now used in the case of tomato plants, pear-trees, and apple-trees; it has been found that in trees that have suffered damage for one cause or other, the scars, etc., are healed up much more quickly when these stimulators are used. Such remarkable results have been obtained that any such term as "limit of growth" almost seems an anachronism. They will permit of two potato crops per year; carrots a full metre in length, and cabbages more than a metre in diameter, have also been known.

'At the time of writing, these growth stimulating elements have only a limited application and their use has not yet become widespread; but in course of time, the picture is bound to become very different, and not only will their range be vastly augmented, but we shall also see the introduction of growth-retarding agencies, and no doubt other forms of growth regulation will be possible in addition.

'Many of the stimulants have the curious characteristic of producing a retarding action if used in large quantities; stored potatoes, therefore, can be prevented from sprouting, and unripe fruit from falling off trees, and a beautiful rose can be made to bloom for weeks on end, instead of only a few days.

'Here are a few quick glimpses into the future: it is autumn, and beneath the wings of our aircraft we can see thousands of acres of ripe wheat. Amidst this ocean of brownish yellow, there appears a square, multi-coloured carpet – a State Farm almost buried in its abundant foliage. How did this oasis come to flourish in a semi-desert region? – how did all this wheat, these orchards and oak trees achieve the power to bloom and prosper on such soil as could normally nourish only stunted scrub? It is all thanks to that great science, chemistry – the enrichment of the soil, the promotion of rain, and the conversion of salt lakes and inland seas into fresh-water ones.

'Or else, maybe, it is freezing, and the winter crops are under dire threat, for as yet they have not had their warm blanketing of snow. Thin ice lies in the puddles and the low clouds just keep on rolling by.

'The pilot heads his plane to a cloud and turns on a spray-gun. Carbon-dioxide crystals give the cloud just that "jolt" that is needed, or apparently needed, in order to set it melting and turn it into snow; for the agronomist had issued a message: "Hard frost expected. Cover crops with layer of snow." If the clouds are plentiful, the pilot will watch his opportunity, but should they be scarce, the meteorologist will see that one is "directed"; and the snow is then promoted in the manner described. Even school children of the twenty-first century will know how rain and snow can be artificially produced. They will know that the "ammunition" from the pilot's spray-gun evaporates, causing great absorption of heat. The mass of vapour in the cloud then cools off, condenses, and issues in drops of water or snowflakes.

'At one time, a summer night frost was a dread visitation that could mean wholesale ruin of harvests; and obviously, on huge State Farm fields, there can be no question of keeping chill at bay by lighting fires; nor would it be practical to bring smoke-boxes by lorry, as the chances are that they would arrive on the scene too late. But this is where our State Farm helicopters enter the picture – a large one for transporting equipment, etc., and a fleet of small ones which serve as "taxis" for farm workers; and so the helicopters, well laden with smoke-boxes, come to the rescue; the boxes are simply jettisoned at intervals as the helicopters encircle the harvest fields, and the crops are saved by the dense smoke that spreads far and wide.

'Naturally, trees do not take easily to desert conditions, for sand contains little in the way of binding and moisture-retaining elements; a process, therefore, that is now under close study and experiment, is that of chemically improving desert and semi-desert soils by the admixture of certain organic matter obtainable from brown coal, timber, petroleum hydrocarbons, and seaweed. For treating the soil with these substances, only a comparatively small quantity will be needed per acre. They will greatly improve the soil's capacity, for absorbing moisture, and will facilitate retention in its superficial layers of elements providing nourishment for plant life. Experiments have already been carried out with quite a wide variety of chemical preparations incorporating these organic substances, and the results have been most encouraging. Where the soil has been thus treated, its texture has improved rapidly, and although it has developed a capacity for absorbing moisture and nourishment, it does not by any means so readily give up these things to whatever is set to grow in it.

'The well-known soil expert, I. V. Turin, goes so far as to state that the advent of inexpensive and easily obtainable soil texture-forming matter is a historic landmark for agriculture, and just as great an event as the introduction of mineral fertilizers and manures in the forties of the nineteenth century.

'But to make land fertile is not enough of itself, there are other considerations besides: it must be protected against pests and diseases, and above all it must be well husbanded – in the fullest sense of the word.

'Out of the tens of thousands of poisons that have been devised up to now, only some few hundreds are in any way suitable for agriculture, and even they cannot be used effectively in all circumstances.

'It is,' continued Volkovitch, 'a fact that in the vicinity of factories where D.D.T. is made flies breed in enormous numbers, and in so far as D.D.T. is a means for their destruction, you may well wonder at this; but it would seem that flies, unfortunately, can develop an immunity to this particular poison, so it will have to be replaced by something else. In agriculture and the world of Nature – and for that matter in medicine too, instances are by no means lacking of organisms becoming adapted to inimical poisons, environment, and so forth; it then behoves biologists and chemists to find alternatives, and in their research, they would do well to aim at such alternatives as could be applied in the greatest possible number of circumstances, or, if practicable, such as are guaranteed completely universal.

'The fields, woods, and other plantations of twenty-first-century agriculture will be made chemically proof against pests and disease, and trees will even have the onslaught of senile decay postponed for years. Future fetilizers will contain an admixture of structure-forming and growth-stimulating elements, insecticide, and disease-preventatives. But as you may realize, for all this to come about, a vast amount of creative work must be accomplished by biologists and their allies in agronomy and chemistry.

'What a pity I haven't been able to take you round a few of the State Farm hothouses! Before long, particularly up north, we shall see large clusters of those long, narrow glass erections extending for miles and miles around every electric power station, and around many factories too; for the great abundance of heat and carbon-dioxide gas thrown off by such establishments will be harnessed so as to permit of setting up hothouse cultivation on a really large scale. Carbon-dioxide gas has properties that make it invaluable as a fertilizer, as has already been proved, and the fullest use will be made of it for this purpose.

'"Thermal agriculture" – an almost unheard of term it may still be, but its real and solid significance will be made manifest in the near future – and here, perhaps, a word or two is due as to the particular role to be taken by electric power stations in this scheme: the output of the orthodox power station consists of electric current and nothing else; their incidental generation of vast quantities of heat is ignored completely, in so far as that heat is ejected from the condensers along with the cooling water into some nearby stream or river – and indeed, it may be found quite often that in the case of these rivers a stretch of a good six miles or so downstream from the power station will not freeze over, even during the very hardest winter frosts; however, there can be no question of thawing out by these means any channel long enough to be of service to navigation; and the efficiency of these power stations must perforce remain at no more than fifteen per cent to twenty per cent.

'Now, however, there is an increasingly large number of power stations where this heat is regarded as no less an item of the output than is the current – in fact, they are stations for the combined generation of heat and electricity. These new thermo-electric power stations produce a little less electric power, but provide consumers with great quantities of heat in the form of hot water or steam, which is available both for industrial and domestic use.

'But there is one disadvantage: although the number of consumers in winter is very high, they fall off in summer. How then can we best use this heat? – for it is inevitably generated, along with the current.

'It can be put to most excellent agricultural use: experiments have shown that if porcelain pipes with openings pierced in their sides are laid in the subsoil, more or less at a level with the roots of vegetables, etc., the underground watering by hot water that can thus be effected will bring extremely beneficial results. So during the summer months, the surplus hot water from these stations will bring a welcome return in the form of better and more succulent radishes, tomatoes, and so on.

'In the twenty-first century, thanks to science, there will be such greatly increased harvests, with, of course, the consequent increase in livestock produce, that it may be doubted whether the need for synthetic food will arise; for the unexploited potential in agriculture is still immense. A further consideration is that no end of edible produce is still absorbed as raw material in the manufacture of various chemicals; such food produce could be substituted by mineral oil, marsh gas, wood shavings, and much else besides. Consequently, of course, a huge amount of food would be freed for human consumption.

'Chemists are now persistently delving into the secrets of photo-synthesis, as a result of which certain organic matter forms in plants, namely carbohydrates and proteins from carbon dioxide, atmosphere, and water. In Nature, photo-synthesis is accomplished without any of the costly and intricate appliances such as one associates with modern photography and matters allied to it. A solution to the problem will point the way to untapping solar energy in all its limitless abundance and harnessing it in the service of agricultural production.

'Another phenomenon that chemists and biologists are much preoccupied with is that whereby atmospheric nitrogen is absorbed by bacteria, a natural process that takes place without any recourse to pressure, high temperature, or catalysers, such as are necessary in industry for the compounding of atmospheric nitrogen with ammonia. A full knowledge of all the workings of this process will lead to cheaper and more rational methods of producing nitrogenous fertilizers from the atmosphere.

'Then lastly, there is an idea that goes back to the time of Mendeliev, and it was he who first wrote about it: that of putting to good use some part of the world's masses and masses of sea-water by allocating preserves for the cultivation of edible marine produce; this kind of cultivation will doubtless apply, in the first place, to the lower type of organism – minute fungi such as the yeast-plant, for instance.

'We have barely yet peeped behind the curtain into the future. What chemistry has achieved so far can only be the mere foundation of the magnificent edifice in years to come. Indeed, there is no doubt at all that the "golden age" of plenty, health, and more and more power for mankind, lies not behind, but in front of us.'

CHAPTER 13

At Neptune's Table

IT is by no means easy, when arriving at the Faculty of Biology, Moscow University, which is on the Lenin Hills, to pick out from amongst all the other numerous departments the room occupied by L. A. Zenkevitch, Principal of the Chair of Invertebrate Zoology and Associate Member of the Academy of Science. Even for those who know little or nothing of biology, it must be very evident, when they pass all the diversely labelled doors of the Faculty, how all-embracing and many-sided this science has now become; for nothing in this world that has life, be it animal or vegetable, would seem to have escaped the biologist's attention. In the artistically designed wooden panels that line the passages, hundreds of small glass-fronted cupboards have been unobtrusively ensconced, and within them is displayed such a huge quantity of every conceivable kind of specimen that the visitor may wonder if he has alighted upon some vast museum; well may he wonder, too, if the day will ever come when biologists will draw up a 'catalogue' of every single organism that the world contains – or has this already been done? – if so, it only remains for the younger generation to envy nineteenth and early twentieth century pioneers who made all the discoveries in Nature.

So when, at length, we found ourselves seated with Zenkevitch, we put this question to him; but he just smiled and we had some inkling that it was not exactly the kind of question that might be addressed to him by students at lectures. . . .

'Now suppose', said Zenkevitch, 'that some party of explorers suddenly let it be known they had discovered a whole continent the very existence of which was totally unsuspected – I suppose you would disbelieve it?

'But it is a fact that something of the sort recently occurred in zoology: Soviet scientists aboard the research vessel *Vitiaz* took from the depths of the Pacific Ocean many varieties of a species previously quite unknown – the pogonophora. These creatures are encased in thin pipes or tubes of anything up to half a metre long; but for all that, they appear to be relatives of ours, as there is a close affinity to the chordates, which, of course, embrace all vertebrates; they are an ancient but highly developed group that the deepest depths of the ocean have kept from extinction – for the minimum depth at which they are found is a fraction under two miles! So to the eight types of living organism known to us is now added a ninth.

'A discovery of only slightly lesser importance was made some time ago by the Danes: from a depth of two and a half miles in the Pacific they took an entirely new variety of shellfish. Externally, the creature has little that distinguishes it from other shellfish, but the more primitive structure leads biologists to think that all shellfish may have evolved from ringed or segmented worms.

'But you perhaps wonder why all this should be so interesting?

'Now it is characteristic that fauna of the extreme depths of the ocean, as in the couple of instances I have just mentioned and in many other instances too, are found to have kept intact some of the primitive features of the ocean's prehistoric inhabitants that have long since disappeared from the surface waters. But down in those very far depths, there has been a stability, a great monotony, in conditions of life for millennium upon millennium, and this has had the effect of retarding evolutionary processes. The true significance behind the discovery of these inhabitants of the ocean depths is that they constitute one more link in the chain of evolution that biologists are trying to piece together so as to get a clear conception of how various groups evolved. At the dawn of the next century, probably, the biological map, so to speak, will not contain any more white patches marked "unexplored"; by that time, the whole course of evolution will present a far more coherent aspect.

'The last decade has been a very important one where the study of the sea is concerned; for you know, it is strange yet none the less true that it has only been in very recent years that the deep ocean depressions have been probed at all – in fact, it was only a very short while ago that they began to "feel" their way, so to speak, down depths not exceeding three miles or so; and at the present time investigation is being carried out in the greatest depths of all, some of which extend almost seven miles! The existence of these depressions was discovered by the *Vitiaz.*

'In 1948, the well-known Swedish oceanographer Hans Petersson, who was chief scientist on the *Albatross* during that vessel's research voyage, brought out his book *The Secrets of the Ocean Depths*, in which he expressed the view that depths beyond about four miles would be devoid of life; in support of this, he referred to the French physiologist Fontaine, who, having placed a living organism in a pressure chamber, observed that at a pressure of 650 atmospheres – the equivalent of the pressure exerted at a depth of four miles, not even the organism's bacteria would live.

'Only in 1947 it was thought that the sea-bed anywhere, at a depth exceeding four miles, would be completely dead; but the research carried out upon our own *Vitiaz* between 1949 and 1952, and that of the Danish expedition on the *Galatia* in 1951 and 1952, showed that life in great variety extends even to the very furthest depths, and that the theory of dead zones beyond a certain depth was a false one.

'But what you are interested in is the future, and not the past.'

Then the scientist who had just been holding forth and discoursing before us with such professional zeal suddenly became a simple and meditative human being.

'Yes, the ocean,' he mused in a tone that rather suggested he could actually see it before him, 'it covers three-fifths of the earth's surface – and how extremely imperfectly known is that portion too! – and when we come to fill that gap in our knowledge, some of the deductions that will be reached must inevitably be of the highest importance to humanity; undoubtedly, too, our ideas upon such questions as the earth's geological past, and even the earth's age will become vastly clearer; in this geological aspect, a particular source of enlightenment should be the sea-bed sediment which has accumulated for milliards of years. In general, the answer to many an unanswered question will be found down in the bed of the ocean.

'How old is the earth? How much has its climate changed? What changes, exactly, have there been in the ocean's level and the outline of the continents it washes? On dry land, geologists count and recount layers of earth time and time again in their endeavours to find answers to such questions. But the continual weathering process, and much else besides, to which dry land is subjected, has brought about disruption in the system of clear-cut layers, causing them to become merged into one another and confused. Here, generally speaking, there are numerous obstacles to the building up of an accurate picture of the earth's past. The atomic "clock" – the method of determining the age of the earth by the quantity of radioactive decay to be found on it cannot satisfy biologists – for they, if I may say so, have their own "clock" – and very probably a more accurate one.

'In the surface waters, unicellular animals and plants keep dying away, and their remains go down to the bottom in myriads, layer upon layer. If, one hundred million years ago, the Barents Sea was warmer than it is now, then in the sediment of the sea-bottom, and at the appropriate level for the period in question, we should find evidence of animal life, such as would be adapted to a warmer climate. The bottom of the ocean is like a huge museum or repository, where there lie in an unchanging temperature, unmolested by any person or thing, "archives" of all the biological phenomena that have taken place in the ocean over literally millions of years. Incomparably more accurately than from any other source, we learn from the sea-bed such a thing, for instance, as the precise course of the earth's climatic changes that have taken place through the ages. Thus, in the Barents Sea area, it has been established that both before and after the Ice Age there were periods when that climate was warmer than is the case now.

'The earth, according to the afore-mentioned "atomic" method of calculating its age, is between two and three milliard years old; but biology must beg to differ here: if we go right back to the beginning of the Palaeozoic Era, that is 700 to 800 million years ago, we find, even at that extremely distant period, that many forms and types of animals are those that we see around us today; basically, they had accomplished their evolution even at that time. Since then, by far the greater part of a milliard years has passed; therefore, it is surely inconceivable, unthinkable, that in the course of the milliard years or so that had elapsed before that time all life, from the very remotest beginnings, had succeeded in reaching a state of evolution perfectly recognizable to us now? – and the impossibility of such colossal transformation within that period of time is surely particularly evident when set against the very insignificant amount of evolution accomplished in nearly a milliard years between then and now? Not even in four to five milliard years, I maintain, could all life in the world have evolved to the state we now know.

'Of course, one might retort, "and what if the pace of evolution was quicker in the earlier period?" But there are no grounds whatsoever for thinking along those lines, and it is much more likely that the truth lies in the very reverse of such a presumption: that at the very dawn of life in the world, evolution pursued an extremely slow pace, but accelerated it later with increasing development. For life to assume its present form, the earth itself could not have taken shape less than ten milliard years ago, and it happens that this figure of ten milliard years – or a bit over – is the one spoken of by the Academician O. U. Schmidt in a new theory of his concerning the birth of the earth and other planets. So in this, biology and oceanography are found to concur with astronomy and astro-physics – a case of sciences that are poles apart enriching each other.

'Some time during the next twenty or thirty years, the masses of ocean deposits will become an object of intensive study; but at present we are not even in a position to say what have been the fluctuations in the saline content of the sea during the time of its existence. But at this juncture let us recall the deep water research carried out in the Black Sea by the *Vitiaz* in 1949. The Black Sea, remember, has only been connected with the Mediterranean for a few thousand years; also, bear in mind that sea-water makes even the soil beneath it salty. Now, in this Black Sea research, when a sample of the bed-soil was taken from a depth of four to five metres beneath the surface, that sample exhibited a water content most highly deficient in salt; thus, almost dramatically, those scientists had penetrated the sediment down to the strata deposited when the Black Sea was a purely inland sea of water that had only a slight saline content. Likewise, in the Bering, Barents, Okhotsk, and other seas, it has been possible to ascertain from bed-soil solutions and animal remains the nature and dates of successive changes in their fauna. At some periods those seas were linked up with the main oceans, and at others they were isolated, then at others, again, linked up; the dates of these alternating periods have been established by the same means; also, of course, it has been possible to trace the chronology and extent of changes in those seas' saline content.

'The furthest penetration of the sea-bed so far achieved is thirty-four metres; but even this modest depth takes us back many millions of years into the earth's history. And now a word as to the procedure. A hydro-pneumatic percussion tube is lowered down from the ship's side. Inside the tube is a piston, and it is something like an elongated bicycle pump. If, having drawn air into a bicycle pump and closed up the opening, you plunge the pump into water, then the deeper you plunge it the more powerful will grow the pressure of the water as it forces the piston against the air. But in this apparatus, the water is not allowed to compress the air thus, for the piston is firmly secured in the 'cocked' position, while the apparatus is plunged down deeper and deeper, the pressure of the water on the immobile piston increasing all the time until it reaches as much as 500 to 600 atmospheres. Affixed to the piston is a thin tube like a syringe needle, and as soon as the piston is released from its secured position the percussion of the water upon it is great enough to drive the "syringe needle" into the bed-soil to a given depth, for the extraction of a sample. The power for working the apparatus, as you see, is supplied by the ocean itself.

'A new type of hydro-pneumatic tube apparatus is now being made which can penetrate the bottom to a depth of 100 metres and thus reach strata as old as ten to fifteen million years; this means that the Ice Age layers will be pierced clean through, and those of the Tertiary Period entered. This year fifty-metre long tubes will be carried by the *Vitiaz*. They are of a type that functions somewhat differently from those I have described: the tube itself enters the soil for the whole of its length. The method is, first of all, to lower the tube from the ship's side by a cable, until the tube's lower end becomes fast in the bed-soil; the cable is then pulled upon as if to haul the tube up again; but in actual fact, this is what makes it sink into the soil for its full length: the lifting gesture hauls up, not the tube itself, but a piston inside it, to which the cable is attached; and the tube, in striving to fill the vacuum that is being formed, slowly sinks into the soil under pressure of the water. This is a new and improved method of taking samples.

'A little time will go by, and then, once more, oceanologists will renew and improve their equipment. The possibilities opened up by modern technique in this respect are almost beyond our powers of imagination. Amongst other things, a means will be found for actually boring the sea-bed to almost any depth. One thing we may be sure of is that a prominent part will be played by deep-water submarines. For the probing of depths at no great distance from the shore, the French already possess a fleet of small electrically propelled submarines which take their power from batteries. But craft like that are useful for little more than reconnaissance trips of half a day or so; what we need are sturdy, sizeable submarines with atomic propulsion – and not only for research work in the depths, but for speedy under-water transit in general. Will we ever achieve such a thing, I wonder?

'It causes us no astonishment to learn that a fish can move under the water at thirty to fifty miles per hour, and we should take this fact as an indication that it would be possible to build submarines of such power and design as could overcome the heavy frontal resistance and travel freely through the water at a depth, say, of 100 metres – such depth, in other words, as would permit of being totally unaffected by any inclemency of the weather on the surface – for after all, look upon it like this: we have learnt to fly through the air faster than the fastest bird, and at such great height as makes storm, wind, and so on a matter of complete indifference.

'Amongst other technical aids at our disposal now is the supersonic hydro-location apparatus, in perfecting which great progress is being made. The apparatus is now increasingly used for the location of whales and shoals of fish. The more compact the environment, the more quickly may sound be transmitted through it; the speed of sound is slowest of all through the air, much quicker through water, and quicker still through dry land or the sea-bed. Modern long-distance locators at coastal stations can "pinpoint" the exact position of a ship well over 600 miles away!

'When you travel along the coast by road or railway in twenty or thirty years' time, an undoubted feature of the landscape will be supersonic lighthouses; but to call them lighthouses is perhaps inadequate, as they might more fittingly be compared with wireless stations, except that their function will be the transmission and reception of messages by supersonic signals, instead of by radio-telegraph. Anything happening in the ocean – any storm or typhoon, any movement, be it of a ship or an iceberg – any conceivable happening, regular or irregular, will be registered and recorded by the coastal station's instruments, which even in the system's infancy will exhibit the most formidable accuracy in taking bearings. When, for instance, a typhoon is raging hundreds of miles out in the ocean, the supersonic instruments will err no more than by a few dozen yards in locating that typhoon's epicentre.

'Or, to take a case like this: far away from land, the ocean bed has been rent by an earthquake, and as a result a wave of incredible proportions is advancing menacingly through the seas, completely submerging whole islands in its course; and now, with gathering fury, this quivering blackish-blue wall ten to twelve metres high is nearing the coast. This phenomenon, the tidal wave, is one of Nature's most terrible visitations. It can completely destroy a whole coastal town and wipe out its inhabitants by tens of thousands – people who a minute or so previously may not have had the least idea that their doom was at hand.

'But with supersonic location no such horror will be allowed to take place. In a mere matter of seconds after the huge wave has reared itself up and begun to travel, the station's instruments will register its force and the direction it is taking. Should the wave suddenly change its course so as to threaten the coast, the recording instruments will automatically switch on a siren warning at any hour of the day or night; and on the loudspeaker system an automatic verbal warning will break in on any other transmission that happens to be in progress, and appeal urgently to all coastal dwellers, telling them to make for safety, either by going a fair distance out to sea in speed-boats, or by going inland and making for localities on high ground. All the material devastation would still occur, of course, but the catastrophe would none the less be greatly mitigated by the saving of human life.

'Well, we have certainly wandered a bit from biology pure and simple, haven't we? – but surely, that is inevitable!

'The point has now been reached when it is going to be possible to exploit to the full all the great hidden wealth of the seas – it is going to be possible to develop and use it on a commercial basis. It should be realized that in the seas there is concentrated, all told, a greater amount of wealth, both organic and inorganic, than on dry land. Suppose, for instance, that the gold content in the whole world's mass of sea-water could be extracted to the full; gold would then become such a common metal that its value would be decreased approximately to that of copper! Certain scientists have, in fact, been trying to devise a method of extracting gold from sea-water, but I fear that so far very little success has attended their efforts – indeed it may be said, though I trust not uncharitably, that sea-water gold, up to now, has proved to be a lot dearer than gold obtained on land!

'However, perhaps in the future some commercially sound and economic way will be found for extracting from sea-water rare and diffused elements of metals – nickel, cobalt, vanadium, and others. But at the moment not even iodine is extracted directly from sea-water; it is extracted from seaweed, which attracts and stores up within itself the iodine content. Recently, by the way, iodine has been extracted with considerable success from mineral oil.

'What is it that makes scientists strive with such persistence to unfold the secrets of the ocean depths and rack their brains over all sorts of complicated problems that confront them in that sphere? Would it not be much more simple, for instance, talking of iodine, to extract it from oil, and not bother about seaweed? Could it be possible that all the riches of the ocean are really nothing but a kind of mirage – enticing but unrealizable, as sea-water gold has so far proved itself to be?

'No! – a thousand times no!' said Zenkevitch with great emphasis, 'we cannot and will not let so much of that great treasure house remain beyond our grasp, when it is almost thrust under our noses! Now, take our trawling industry. I say "industry", but is the word really justified? For despite the high standard of modernization observed by our trawling fleet in the matter of methods, equipment, and so forth, what, after all, is trawling, but "hit or miss" – a pursuit more in the nature of hunting than anything that goes by the name of industry! You see, just to catch fish, kill whales and go after certain dainty invertebrates like lobsters and oysters simply is not enough: the whole mass of the marine animal population must be mobilized in human interests. In the next century,

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enormous and most rationally organized marine industry will serve humanity; and just as agriculture is sub-divided into market gardening, forestry, sheep rearing, and so on, the marine industry will also have several distinct branches, one of which will be whaling.

'Now, having mentioned the subject, it occurs to me that a few words about whales might not be out of place: if a whale was born today, have you any idea how soon it would begin to breed?' said Zenkevitch, showing he expected our reply.

We feverishly racked our brains for every scrap of knowledge we could ever have picked up about whales; we remembered that they can be dozens and dozens of yards in length, and that they can weigh ten or fifteen tons. But not being biologists, we were unable to form the slightest notion as to how long they take to reach maturity. 'Most likely, ten or twelve years,' we faltered.

'You needn't be ashamed!' said Zenkevitch with a reassuring smile, '– plenty of others have made that same mistake. It is very well known that the largest land mammal, the elephant, takes anything from thirty-five to forty years to become fully mature; but extremely few people know that the whale – the sea-elephant, so to speak – becomes fully adult and starts to breed in its second or third year. The vast majority of people, when they learn of this, are utterly baffled as to how the animal could ever grow at such amazing speed; but to biologists, if I may say so, it is all very understandable: the sea is immeasurably richer than dry land in nourishment and vitamins.

'On land, vegetation must have firm stalks, well protected with husk-like sheaths, so as to withstand winds and to incline towards the sun's rays; also, it must possess roots that are sufficiently firm, multiple, and widely spread, to take sustenance from the soil and to reach down to moisture in the depths; it must also have the means of protecting itself in conditions of drought, excessive heat, or excessive cold. Just think of all the energy that must be consumed in developing and maintaining these protective adaptations! – and how comparatively meagre seems the amount of sustenance or useful material that can be produced for human beings, after all the rest has been attended to!

'But in the marine sphere, things are ordered very differently – no question here of any protective husks and all that veritable arsenal of defence that land plants must have! Marine vegetation consists, almost in its entirety, of those same cells and organic substances that, generally speaking, are present only in the foliage of land plants. If I may draw upon the language of technology for a biological context, I will say that the "efficiency" of marine plants in production of content fit for human or animal consumption is very nearly 100 per cent, while that of land plants does not exceed five or six per cent. This is because, in the seas, conditions are ideal for plant life: there is nourishment in the whole of the surroundings; the temperature is almost constant, year in, year out; and plants can live without taking root. Not for nothing is it that life on the earth would appear to have first begun in warm ocean lagoons saturated by the heat of the Sun's vital rays.

'But we have to consider other things besides the great abundance and accessibility of the nutritive matter on which marine organisms thrive; it is not only a question of quantity, but of quality also – the fact that, in general, a far greater concentration of vitamins is to be found in marine plants than in anything that grows on land. This particularly applies to what are called plankton – vegetable and animal organisms of microscopic proportions that abound, most of all, in the surface waters. Incidentally, it is interesting to note that the nutritive value of vegetable plankton falls only very little short of that of the finest meadow hay.

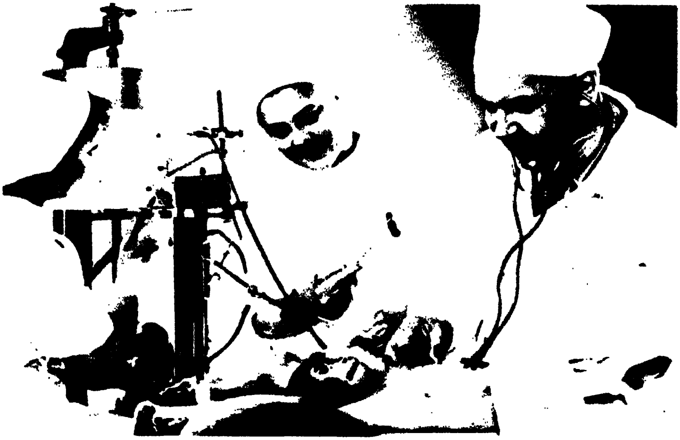
'Well may these comparisons set us wondering how such things can be – how it is that we lavish so much loving care over hay and strive not to let a single crumb of its organic substance be wasted; yet while we sweat over such toil on land, the sea's huge multitudes of various organisms, its incalculable riches, remain untouched. Here you may retort: "But what of all the things we *do* get from the sea – seaweed, shell-fish, crustacea, and so on?" But can we say it is really much? – is it not only a microscopic flea-bite of the sea's total wealth?

'By the way, there's a bit of news here about what our Czech colleagues are doing.' Zenkevitch opened a periodical with a gaily designed cover. 'Look,' he said, 'very soon they are going to use, on a really big industrial scale, chlorella – a green fresh-water seaweed.'

He then read out: '"Chlorella is valuable both as a source of cattle fodder and as a source of raw material in the manufacture of fertilizers, spirits, benzine, and various medicaments. From one hectare of water-surface in the sea-weed reservoir about twenty times more fodder can be obtained in the course of a year than from a hectare of the very best quality hay."

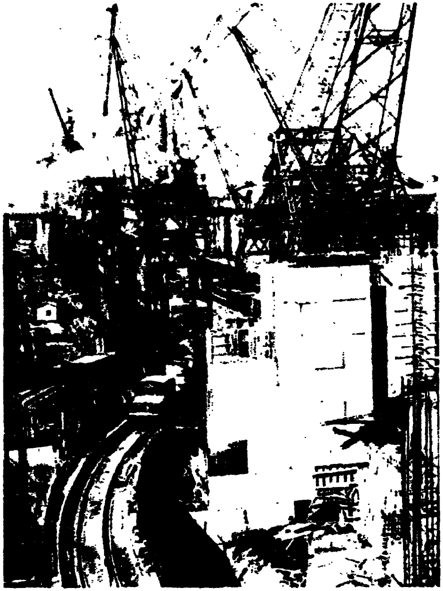
'In what other respects is marine-culture advantageous? Take this case: you may allocate a certain area of forest for tree-felling; so every tree in that area is cut down, after which, young saplings are planted to replace them – but, rather similarly in a certain respect to the elephant (forgive me please, for the comparison!) those saplings will take a good forty years to grow up and form adequate replacements! But marine organisms, which, taken in bulk, account for the lion's share of the Earth's vegetation, give off as many as fifty generations per year!

'So now, perhaps, you are beginning to realize why whales grow up in two to three years instead of forty; they have evolved the instinct for obtaining from the seas an extremely satisfying and adequate diet. Whales, of course, are no exception in this, but I have mentioned their case, as it provides such an excellent illustration; thousands of others could be given, amongst which some quite intriguing ones, such as may well make us pause and reflect on the laws of Nature – in fact, it is almost as if she has created miracles under our very eyes, which she points to and says: "Look! – learn!"



(a) Professor Negovsky makes a body-cooling experiment on a monkey, while perfecting the life-restoring tests aimed at reviving the heart muscles and averting premature death during delicate operations

(b) A dog with the transplanted head and forelegs of a puppy in experiments which Professor Demikhov is carrying out so as to be able in the future to transplant healthy organs to human beings in place of injured ones

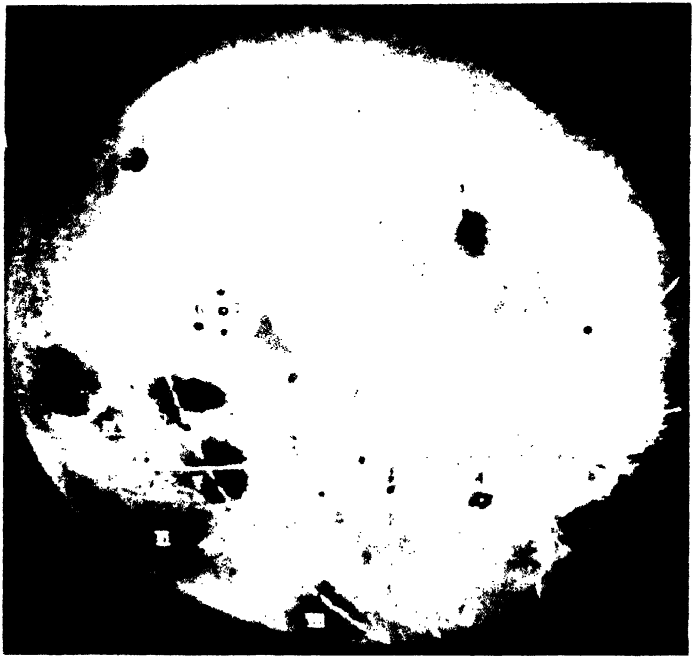


(a) The channel of the Volga being barred from the floating bridge at the construction of the Kuibyshev hydro-electric station

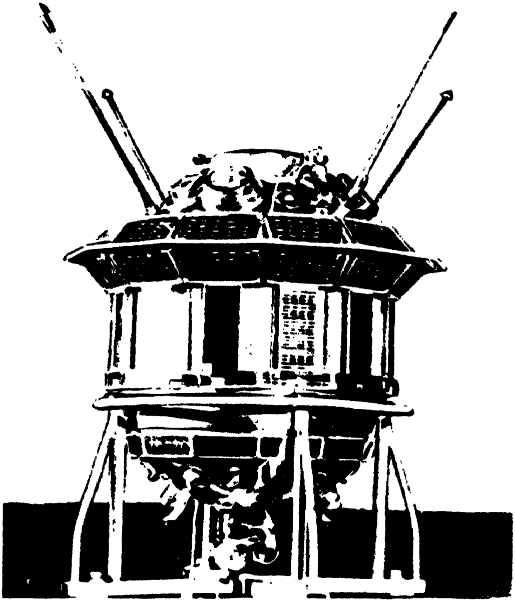
(b) The Stalingrad hydro-electric construction project

(a) New designs of space suits for pilots being tested in special altitude chambers which reproduce high altitude and space conditions

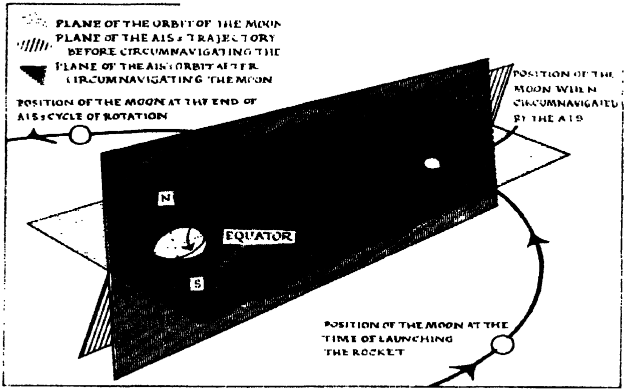
(b) A Soviet space man with his altitude suit and hermetically sealed helmet



The reverse side of the moon, photographed by the automatic interplanetary station



(a) The automatic interplanetary station


PLANE OF THE ORBIT OF THE MOON
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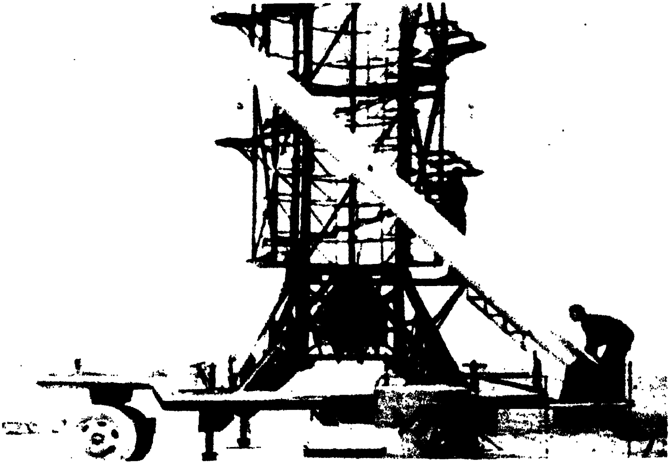
POSITION OF THE MOON AT THE TIME OF LAUNCHING THE ROCKET

(b) The chart of the trajectory of its flight

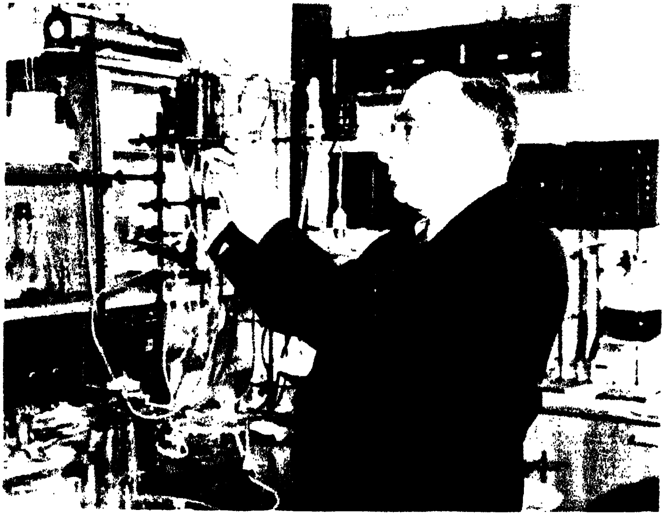


(a) A meteorological research rocket being set on the launching tower

(b) A container with geophysical equipment, successfully recovered from one of the earlier launchings of Russian rockets

(a) 'Courageous', one of the two dogs, and an unnamed rabbit successfully launched into space in a Russian single-stage rocket. The animals returned to earth and their condition was reported as 'good'

(b) Training is now taking place in the Soviet Union of the first space man. Here, registration apparatus is being fixed to a space man, prior to tests in the altitude chamber



(a) A. N. Nessmayanov, President of Soviet Academy of Science, a world renowned authority on organic chemistry

(b) Academician A. Vinter, the doyen of Russia's hydro-electric power engineers

(c) I. P. Bardin, a Vice-president of Academy of Science and a pioneer of Soviet metallurgy

'Have you ever wondered how it is that the largest mammals in the world feed only upon the very smallest vegetable and animal matter? Both in size and in strength, the whale and the elephant are perfectly well cut out to become carnivorous; but they are not carnivorous, and in this is seen a natural law: both the ocean – the whale's habitat, and the tropics – the elephant's habitat, are places so generously endowed by Nature that vegetarian animals are more favoured than carnivorous ones; in such conditions, it becomes increasingly difficult for large beasts of prey to feed themselves; Nature would seem to tell them: "If you want to be a larger, stronger, and more agile and capable beast – qualities which are vital in the struggle for existence – then change your diet – become a vegetarian. Maybe you will find it less satisfying than the victims you kill, but on the other hand there is infinitely *more* vegetarian food all round you, and you will save yourself all the tremendous physical exertion of tracking down your prey and fighting for it with others of your kind, or with the intended victims themselves."

'Of course, though, they would have to become adapted to the change of diet – and there are, indeed, instances of former carnivorous creatures that have actually effected this change: now, which is the world's greatest fish? – the shark, isn't it? But which shark – the carnivorous variety? No! – the greatest shark of all has ceased to be carnivorous; it has a bone plate at the entrance to its mouth for filtering through plankton-laden liquid, almost exactly like the whale's baleen plate – otherwise called the whalebone. The ancestors of this shark were carnivorous, but none of them ever reached the size of this sixteen-metre long innocuous Titan which grazes peacefully through the ocean pastures.

'So you see what the powers of Nature can accomplish, and if only the exact means she employs to achieve such wonders could become a part of human knowledge, then it would be within our grasp to emulate her.

'The whale's baleen plate is a most simple adaptation; but, so far, human ingenuity has quite failed to devise any kind of filter that can compare with it in efficiency and reliability for extracting plankton from sea-water. Special types of ship have even been constructed, with gigantic centrifugal pumping apparatus for straining out plankton. But as yet none of these experiments have given such results as would economically justify the methods used; doubtlessly though, in about ten years' time, a satisfactory means will be found, and then plankton will be made into fodder for cattle and other farm animals; and it is even possible that it would be suitable for human consumption.

'Seaweed, for a certainty, will be most widely used in the next century – no proper estimates have yet been made, but the total supplies of it in the world must run into milliards of tons, and, of that quantity, all that we use at the moment are some hundreds of thousands of tons.

'It is my conviction that towards the turn of the century a new science will be born – submarine agronomy, or, if you prefer it, submarine genetics. In the Barents Sea, the Baltic, the Sea of Azov, and the north-west of the Black Sea, numerous small bays and inlets will become reservations for Marine State "Farms". Here, in depths not over a hundred metres or so, where the water is penetrated by the sun, agronomists and their staffs will go their rounds in diving dress, riding in swift under-water conveyances, tending the cultivation of all sorts of useful marine plants and creatures; they will, moreover, by careful selection and breeding, create new varieties in marine products – animal and vegetable. Only down in the greater depths, where it is dark and the temperature hovers between 1 and 2° C. – where there are obstacles to the development of life in any form – only down there will submarine "meadows" and "market-gardens" be absent.

'It could well be that with the advent of spring the plants under cultivation would be starved of phosphorus and nitrogen, for such none-too-generous quantity of these elements that the sea water does contain would be absorbed by the rapidly shooting seaweed, which is a perfect glutton for them. Therefore, I wonder, could that situation not be forestalled through prior satiation of the seaweed's hunger – in other words, by dissolving in the lagoon a solution of phosphorus and nitrogen in great quantities; would it be too optimistic to suppose that the greater the quantity thus dissolved, the better the ensuing harvest of cultivated plants, owing to their absorption of the sea-water's phosphorus and nitrogen, which would normally be monopolized by the seaweed? But it would really need an expert in marine vegetation to pronounce upon a question like that – and it is true, indeed, that on the land, fertilizers are not introduced during winter, and I suppose it would all amount to a question of knowing just when marine plants should be given fertilizers, and what kind of fertilizers should be applied – the whole enterprise will certainly be no simple matter.

'The breeding of sea mammals will be carried on; but as for whales, I hardly think there could be a question of rearing them in any kind of reserved breeding ground – probably, it would be a much better idea to regard the seas of the whole world as their rightful breeding ground, for it is evident that the creatures' orbit is a very wide one indeed. You know, whales frequent the Antarctic regions only in summer; at the approach of winter, they make a journey of thousands of miles to the sub-tropics. Nobody yet knows where they breed, or what routes they take in their migrations; nor is it known whether the shoals met with in the southern hemisphere are the same as those met with in the northern hemisphere or different ones. The whaling industry badly needs proper control and regulation; recently, though, the first measures for the protection of whales were agreed upon and put into force, and if these are conscientiously observed by all parties there is hope that whales will not only keep their shoals as now, but will even increase them.'

Zenkevitch paused a second. We could see that, having become so engrossed in matters close to his heart, he could have gone on telling us a vast number of other extremely interesting things.

'I am afraid you will have to excuse me,' he announced,

'– time has simply flown, and there's an examination I have to attend to.'

He took us to the glass door of his study; on bidding farewell, and opening it, he greeted a young student who had been waiting patiently outside in the passage: 'My dear young man! – you really must forgive me . . .'

CHAPTER 14

Creators of Living Nature

'IF you only knew,' Professor Roman Antonovitch Jebrak of the White Russian Academy of Science said to us, 'how pleasant it is to be a biologist today, to be engaged in a science which has such a spectacular future. The twentieth century has often been called the age of physics and biology. Given the fact that the first half of the century has been characterized by important discoveries in the field of nuclear physics, it is beyond doubt that the second half of the century will be noted for great discoveries in the field of biology.

'Nevertheless, to be precise, we must remember that the first half of the twentieth and the latter half of the nineteenth century have brought mankind great biological discoveries. Among the most important in the nineteenth century, according to Engels, were the discovery of the laws of the conservation of energy, the elaboration of the cellular theory, and Darwin's theory of evolution.

'In the twentieth century methods have been found to reconstruct the cellular nucleus, giving us a new and revolutionary insight into the secrets of life.

'What is the importance of this discovery? For thousands of years man, in his attempt to develop new animal and vegetable forms, could only use the materials afforded by Nature herself. He was constrained to live on her "charity". Until now scientists had to be content with wretched fragments of Nature and to adapt them to plants and animals in order to obtain new types. Only comparatively recently have we discovered the possibilities of extending the limits of variation of plants and animals. To achieve this we had recourse to hybridization, in other words the crossing of more or less similar species. To what extent this amplified the biologist's possibilities can be judged from the work of I. V. Michiurin, who evolved hundreds of new species of hitherto unknown plants.

'Hybridization even today remains an important weapon in the biologist's armoury, but in addition to this over the past ten years science had added new methods of dealing with heredity. Let us speak of these methods now.

'Today every student knows the constitution of the atom, that microscopic "brick" in the edifice of the world. He knows that at the centre of the atom is to be found the positive nucleus and that the negative charges, the electrons, rotate about the nucleus. Almost the entire mass of the atom is concentrated in its nucleus, which consists of neutrons and protons. This structural pattern of the atom is very similar to that of the living cell. In this, too, exists a complete nucleus, the carioplasma, surrounded by a liquid, the cytoplasm. We have not referred to this analogy by chance. Admittedly the atom and the cell are two different things but research and transformation of the cellular nucleus, as experience has shown, offers mankind the same fantastic possibilities which it has been given in the study and splitting of the atom.

'The discovery of the secrets of the atomic nucleus in the first half of the twentieth century has brought about a complete revolution in physics. A similar revolution is taking place today in biology. Today the eyes of the scientists are focused on the nucleus of the cell.

'During the past few years much data has shown that the heredity of organisms depends not on the cytoplasm but on the nucleus of the cell. If we unite in a single cell the nucleus of one cell and the cytoplasm of another we shall develop animals which only retain the characteristics of the one from which the nucleus has been taken. Such experiments have been carried out by the Soviet scientist, B. L. Astaurov, on certain hybrids of the silkworm. Experiments have also been made abroad, but the general conclusion is the same: if heredity depends basically on the nucleus of the cell obviously by changing the nucleus we can also change the heredity. But is this true?

'The first experiments carried out to solve this problem were made by Professor I. I. Gherasimov at the end of the nineteenth century in the botanical laboratory of Moscow University. Gherasimov succeeded in obtaining cells with two nuclei, and cells with none. The latter did not separate and in consequence died. But the cells with two nuclei increased in size and vitality. This phenomenon, in other words the increase, at the behest of man, of the number of elements in the structure of the nucleus of the cell, is known as polyploidy.

'A few words now about the basic nuclear elements, the chromosomes. It has been established that the chromosome consists mainly of albumen and has a fairly simple chemical composition. Just as the various departments of the brain rule the various parts of the body so the chromosomes exert various influences on the development of characteristics and properties of the organism.

'For each biological type there is a specific and constant quality of chromosomes in the nucleus. The form of the chromosome is constant and does not change visibly for many generations. Its most outstanding feature, however, is the fact that it is always disposed in pairs. Independent of the number of pairs of chromosomes in the nucleus in each pair, one originates from the father and the other from the mother. They are bound to each other as though they were magnetized. Continuing our comparison with the atomic nucleus the chromosomes can be compared with the neutrons.

'In addition to diploid organisms, which have two types of chromosomes in the nucleus of the cells, there are in nature a number of plants which have four types of chromosomes (tetraploids). In the Arctic zone, the desert, and the high mountains there are many types of polyploids. In the flora of the Pamir, at high altitudes, these amount to eighty-five per cent, while at Spitzbergen eighty per cent of the flowering plants are polyploid. Organisms are also found with three types of chromosome. . . .

'But why have we embarked upon a discussion about polyploids? The study of polyploids has shown that normally these are far larger than the diploids and grow more rapidly; that their cells are larger and form more fats, sugar, albumen, and other substances which aid the plant to accustom itself to its environment. These plant qualities are of the greatest interest to man. Among the cultivated plants, many of which are polyploid by origin, we find wheat with four types of chromosome and also the species of long-fibred cotton on which the Soviet cotton production is based. Many polyploids with a high chromosome content are to be found among apples, grapes, bananas, and flowering plants.

'The greatest perfection in cultivated plants has been reached with types having a high chromosome content. We have species of wheat with 14, 28, and 42 assortments of chromosomes. The greatest value is possessed by the type with a soft ear. Other varieties of soft-eared wheat with a high chromosome content have the highest resistance to winter frosts. Ninety per cent of our wheat crops today consist of this species.

'But how can we obtain polyploids? In the normal subdivision of the cell the number of chromosomes doubles itself, producing two cells. To obtain a nucleus with double the quantity of chromosomes, for example the tetraploid from the diploid, the cell must not be given a chance of subdividing once the chromosomes have separated. If the cell with the chromosomes which are on the point of subdividing is frozen or treated with a drug the mechanism of the separation of the chromosomes towards the poles is arrested, the cell does not split and the chromosome contained in it becomes a twin. Gherasimov applied this method to algae, thereby obtaining the first artificial polyploid produced by scientific methods.

'Today mankind satisfies its alimentary needs with those precious species born of age-old natural selection, or by producing them artificially. But in the near future we shall have new types of corn obtained by a modification of the nuclear cells.

'Recently by experimental genetic methods we have obtained corn with 56 and 70 chromosomes. According to theoretical calculations it will be possible to create corn with a far greater number of the structural elements of the nucleus:

84, 98, 112, 126, and 140. These new forms will undoubtedly be obtained in the course of the present century.

'By the year A.D. 2000 we shall have developed cereals with far stronger stalks. Mechanized production needs new species with a stalk that does not bend before the wind, and which in the majority of cultivations do not actually exist. New methods will enable us to create them. We shall eventually change the biochemical characteristics of the ear, its quality and nutritive power.'

Professor Jebrak had good reasons for making such bold forecasts. It was impossible to discount his enthusiastic belief in this biology, which after hard work has created a corn with an extraordinary high number of chromosomes (56 and 70), far heavier than the ordinary species, with a stalk that does not bend and with a great resistance to disease.

'Tell us, Roman Antonovitch,' we asked the professor, 'shall we be able to go on increasing the number of chromosomes in a plant? Is there a limit to the return a farmer can expect?'

'In practice,' replied the professor, 'the number of chromosomes can be increased indefinitely. They only need to be in pairs. As to the return in farming the essential source of the creative energy of organic substances on our planet is the sun. Plants today normally absorb from two to five per cent of this energy. On an average our fields absorb about three per cent of solar energy. The remaining ninety-seven per cent constitutes our reserve. To reach the latter we must create new plants with large leaves, to increase the biological coefficient of useful action. This is an arduous and difficult undertaking. But the harvest does not depend solely on the sun. Men have learned to feed the plants and to provide them with water. The chemists will provide richer and more varied fertilizers for the plants of the future. Already today we can raise corn production 100–120 quintals per acre. We should eventually be able to harvest from the fields outside Moscow as much as 140 quintals per acre. But for such a harvest we should have to stake every plant! It is not enough then to nourish the plant, it must also be given "strong legs", a stalk which does not bend under the weight of the ears. The problem of the strength and resistance of the stalk is one of the important "keys" to increasing the harvest.

'The biologist of the twenty-first century must be an expert builder of plants. Already today, in cultivating new types of plants with new qualities, we have to take rigorous account of heredity and a number of other factors in the way that the architect has to calculate dimensions, shape, and solidity of materials.

'The comparison of the biologist with the architect is only an image. In reality his work is far more complicated, because man cannot direct Nature as he directs a machine. Our power is limited to the study of Nature and the capacity to use her laws. You propose to give cereals a longer life, you plough the soil, sow, and think that each year you will have a good harvest. But this is not the case. So that the apple may live fifty to sixty and sometimes a hundred years, every plant which has only one year of life must be pruned. If this is not done the apple will cease to give fruit. We still do not know whether long-lived cereals will prove useful.

'Biological construction requires not only complicated calculations but a host of experiments. Let us say we want to grow peas on an acacia, which is of the same family. In this way we shall have a long-lived pea. But the result may be a hybrid which will resemble neither the acacia nor the pea. Remember Bernard Shaw's famous retort to a well-known actress: "I should like a son by you," she said. "It would combine my beauty and your intelligence." Shaw was no biologist but he replied: "But how can you guarantee that it will not be born with my looks and your brain?"

'You propose to shorten the stalk of a plant giving the nutritive substances the possibility of passing from the root to the ear. But the shorter the stalk the less leaves it will have. And the leaves are the plant's nourishment. You see now the difficulties which face the biologist who wishes to remould Nature. Nevertheless, biology does not abandon the struggle but overcomes the difficulties. Let us return to our polyploidy. This progressive scientific method already makes a visit to certain orchards, in Sweden for example, a dangerous undertaking. I am sure that you would not like a two-pound apple to fall on your head. And yet such apples have been grown.

'Take for example a seedless melon. Once this would have appeared a fairy tale. Today huge seedless water melons are grown in Japan and other countries. I should like to compare this water melon with a mule because it is in fact a "vegetable mule". The mule, obtained by crossing a horse with a donkey, is sterile, as is the seedless water melon, which is obtained by crossing a diploid with a tetraploid melon. But to compensate for this it is all pulp and the edible part is increased by thirty to forty per cent. For what reason? Because the nutritive substances are not wasted in nourishing seeds and the rind but turn to pulp.

'Within a few years we shall be able to enjoy stoneless cherries and plums. In fifty years' time the size of fruits will be doubled. In fifty years! To appreciate the extent of the revolution taking place in biology today remember that man has doubled the ear of corn in fifty years.

'Polyploidy affords a marvellous example of the change of the quantitative to the qualitative: the well-defined increase of the quantity of nuclear matter (chromosome) is accompanied by the change of the hereditary nature of the organisms. By obtaining polyploids man will be able to create new species which do not exist in nature. But polyploidy is only one of the methods of selection used in modern biology; to act on the nuclei of the cells with the aim of changing the hereditary qualities can also be accomplished by radiation.

'To transform the chromosomes in plant cells either the seeds or the plants themselves are subjected to radiation. On the field is installed a kind of tower containing radioactive cobalt. Small instruments of this material can be applied to the branches of the trees to radiate the buds of apples and other fruit trees. Under the action of the alpha and beta particles or the gamma rays given off by the radioactive substance the structure of the chromosome is changed. Apparently the chromosome is split into fragments which subsequently rejoin and grow together. But occasionally they reform in a new combination. It suffices for some part of the chromosome to change position or for a fragment of one to become attached to another to change perceptibly the hereditary features. The same happens when the chemical structure of some part of the chromosome is changed. Beneath the action of the rays the quantity of hereditary mutations increases many hundredfold. In every thousand changes one or two will be advantageous to mankind. This is why biologists will have to spend a lot more time in the selection of the best plants.

'With the aid of nuclear energy we have already obtained types of barley, white mustard, wheat, flax, rice, and other plants which give the highest return. Extraordinarily important to science and to agriculture within the next half century will be the regulation of the sex of animals, enabling us to obtain at will so many males or females. This will substantially increase the numbers of our cattle and poultry. Today, by introducing an electric current into a solution of seeds, biologists have succeeded in separating the spermatozoa which determine the sexes of the organism. By this separation we shall be able to apply this method to artificial insemination.

'Normally a new cell, which is initially a new organism, is formed by the union of male and female nuclei. An organism of this nature bears within it the combined features of the father and mother. But as we have already mentioned, as a result of experiment we have accomplished the fusion of completely different nuclei. Scientists have fused two male nuclei with the result that the offspring are all male. In the same way, if we wish we can obtain all female. Treating one sterile female sexual cell of a silk-worm with boiling water or with hydrochloric acid, Professor B. L. Astaurov has actually obtained this result.

'Biologists have learned to determine the sex of the males in the first stages of development. In poultry breeding, for example, day-old chicks have been selected and the cocks separated from the hens. In silk husbandry a method has been devised of determining the sex of the worm in its embryo stage. A Japanese scientist devoted twelve years of his life to the solution of this problem. What did he do? Subjecting the moth to X-rays, he attached part of the chromosome with the gene which determines the colour of the egg to another chromosome upon which depends the appearance of the female. But this appendage decreased the vitality of the caterpillars. A second surgical operation was necessary, with X-rays to cut off the superfluous parts. In this way was created a species of moth which laid eggs of two colours – one grey, from which emerged the female, and one white, from which emerged the male. An apparatus equipped with photoelements easily selected the eggs. What was the aim of this experiment? With similar feeding the males give thirty per cent more silk than the female. This new type of silkworm was also produced in 1957 in Soviet Central Asia. The miracle of today will become the commonplace of tomorrow.'

CHAPTER 15

The Age of Radio

A SUPERSTITIOUS amazement, an almost idolatrous sentiment was aroused in people in ancient times by the marvellous properties of magnetism – the natural magnet which attracts metal objects and amber which rubbed on cloth will attract and hold pieces of paper and small feathers.

Many centuries were to pass, however, before men understood the existence of the bonds between the electric and the magnetic fields. The genius of Faraday was necessary before Hertz could open a breach in the field of electro-magnetic oscillations.

In actual fact electromagnetic oscillations, the science of which has existed barely half a century, have fabulous possibilities.

Is not a conversation between friends at a distance of several thousand miles, from one continent to another, miraculous?

Is it not extraordinary that you can see clearly in the total darkness of a starless, moonless night when a man cannot see a yard before his face?

Is it not fabulous to be able to transmit several hundred miles a moving picture which preserves its outlines and all the wealth of its colours?

Is it not stupefying to be able to hang in the air, to bring to white heat, and eventually to melt a piece of metal without touching it?

This list of marvels, which not long ago were unthinkable and which with the discovery of electromagnetic oscillations have today become everyday reality, will continue to increase. If we check the data of every miracle accomplished we shall observe that the further we advance in time the more surprising and numerous will be the discoveries in the field of electromagnetics. At the outset it was one discovery every ten years, then every year, and today the rate is several per year.

How many ideas on the application of high frequency waves still wait to be discovered?

We shall have wonderful machines which move slowly over virgin soil enveloping it in a cloud of smoke and leaving behind a finished highway, smooth and bright as a mirror.

We shall have cars and other transport vehicles without fuel tanks, without even wires to carry the propulsive power. They will not even have inside aerials to receive the radiated power.

We shall have aircraft which will fly for thousands of miles without using a drop of fuel.

We shall have an artificial sun which will burn day and night over the capitals of the world.

We shall have incredible machines for exploring distant planets and communicating the results of their explorations to the earth. . . .

Many scientists spoke to us of the hitherto unexplored fields in the branch of electromagnetic waves and high-frequency currents. We shall refer to only a few of the more important.

*

Vladimir Alexandrovich Kotelnikov's study is in the old building of the University on the Moskovskaya. Here, in the place once frequented by Pushkin, Lermontov, Lebedyev and Jukovski, Timiriasev, and Stoletov, the greatest Soviet expert in radiotechnology spoke to us of the science of the future:

'Radio is still in its infancy. A mere sixty years ago the scientist A. F. Popov presented the Russian Physiochemical Society with a treatise entitled: *Concerning the relationship between metallic dust and electric oscillations*. This dry title concealed a great discovery, the results of which we cannot even envisage today.

'It is not easy to foresee what radio will be like in fifty years' time. It is as though at the time of the signaller of Popov's era, in the first experimental years of radio-communication, someone spoke of a television or a radar set. He would have been taken for a visionary. But I am convinced that in this second half of the twentieth century radio will be characterized by new important discoveries and equally important new practice. We cannot naturally envisage all these possibilities. Let us, therefore, speak of the innovation which to date has given the first positive results.

'The general trend in the development of radiotechnology in the past years has been the use of short waves. Every five years – the figures are only approximate – the length of the waves discovered is reduced by five volts. There is no shadow of doubt that this assimilation process of the ultra-short wave will soon develop. If we work with waves measured in centimetres, in a short time we shall undoubtedly be using waves of a fraction of a millimetre.

'At first sight the process of obtaining ever shorter waves has a quantitative character. Nevertheless this quantitative change may lead to a complete series of revolutionary qualitative changes. Everyone has probably read in science fiction a description of tiny transmitters and receivers with which the future inhabitants of the world will be able to converse at any moment and at any distance.

'Millions of radio stations will work simultaneously. Where will so many waves be collected when already the field is congested? Today we cannot carry out more than a few score of television broadcasts at the same time. Only by obtaining millimetre or ultra-short waves shall we be able to use an almost unlimited number of channels not only for radiotelephonic networks but for televised transmissions.'

Kotelnikov spoke and before us opened a page from a science fiction novel.

It is early on a holiday morning. Yesterday evening we forgot to arrange with a friend for a trip into the country. We pick up from the bedside table a small object resembling a cigarette holder. It is a receiving-cum-transmission television set for private use such as every inhabitant of our planet possesses. We give the call signal of our friend and press a button. If the small oscillations run across the green screen of the receiver it means that the recipient is engaged. But our friend at the other end has a gadget which announces our call. It is up to him whether we are tuned in to his conversation or whether we have to wait until he is finished with the other caller.

His conversation did not happen to be private. Our screen cleared and on it appeared a familiar face outlined so clearly by the electronic ray that despite the smallness of the picture we could see the hairs of his eyebrows and his freckles. At the same time the sound came on, telling us that the subject of the conversation was identical – our trip to the country.

Now the face of the other speaker appeared on our screen. We took part in the conversation and the screen did not fade; we saw the two faces, followed their expressions and thought: 'How could the people in the first half of the twentieth century speak by radio and telephone without seeing the face of the caller?'

A discussion ensued regarding the route of the trip. We needed to glance at the map. Despite the clarity of the picture, the map of the Moscow region, the size of a postcard, was certainly not suitable for the precise itinerary of a car drive outside Moscow. We therefore switched on the drawing room television with a screen covering the whole of one wall. On this appeared a huge map in the tent of a friend who spends his holidays about sixty miles from Moscow. We were able to choose the route as though the three of us were all sitting in the same room.

The trip was very amusing but it would have been a pity to miss the football match which was being played in the Lenin Stadium. We followed the game on our portable sets. On the green banks of the Volga we saw all the stages of the football match. . . .

'Yes,' said the professor, 'we shall certainly have these tiny television sets which will go in the waistcoat pocket, and also huge screens many square yards in dimension. A great screen will require a large set. The television will be like a picture . . . the whole set will be flat and the thickness of the screen will be minimal. The increase in the size of the television and all radio sets will allow us to use semi-conductor elements.

'A further revolutionary transformation will be effected by the use of ultra-short waves in chemistry. The actual oscillations of these parts can coincide with this or that frequency of the radio waves. Radiating the substance by short waves of various lengths, we can smash and destroy the parts of the molecules, changing their structure; in other words, we can change their chemical composition.

'By the action of radio waves we shall accelerate radiation to a greater degree than that obtained by the strongest catalysts and we shall be able to effect processes which today cause unending toil or are considered impracticable.

'Of course these are only projects today. Many years of work will be necessary before these ideas become concrete reality, by the study of various reciprocal actions of various substances and various radio waves. But I am sure that the birth of a new science, radiochemistry, is imminent and that this science will soon have a great creative maturity.

'I should like to draw your attention to another interesting field which is in constant development, but which will not be successful until we have perfected electronic radio. I am referring to the electronic calculating machines or electronic brains. In the twenty-first century these machines will be in general use.

'You will find one on the office desk and it will take up no more room than a present-day typewriter. From it issue blank sheets of paper, but there are no keys and letters, without which we cannot imagine a typewriter today. Only six or seven small knobs will be seen on the front of the machine.

'To make it function we press a knob. Now we speak on a subject of interest – for example, science. Ten minutes are spent in conversation, punctuated with questions and answers. When the conversation is ended another button on this twenty-first-century machine is pressed. From it issue a number of sheets of flimsy paper covered with very readable type. These sheets give the accurate text of the conversation. The machine has also corrected badly constructed sentences better than the most expert typist and has made a point of reproducing the greatest precision of thought. Not all the sentences are well turned, some of them are clumsy, but all are grammatically correct. This could not be said of the recorded speech. On other sheets the machine has translated the same conversation into Latin and English. The translation into these languages is made by pressing another of the buttons.

'Such a machine which types and translates automatically is not so fantastic from the point of view of modern science. We already possess machines which can translate from one language to another. True, they are very cumbersome, have a limited vocabulary, and are confined to scientific texts. It is not impossible to build a machine to correct the literal text, because the structure of any language follows certain rules and the machine is capable of obeying all the laws we set it.

'Today these machines cannot yet absorb the human voice directly and work on the basis of texts registered on a tape recorder. But this difficulty will be overcome, and doubtless in time the direction of many of the machines will be in the form of orders given by the human voice.

'Now let us talk briefly of the transmission of wireless energy. I do not mean the small amount of energy which a radio set receives from its aerial but the transmission of sufficient power to set in motion an aeroplane propeller. This problem will be solved. The aircraft in flight will receive power directly from the ground below in the form of a high-frequency beam similar to the beam of a searchlight.

'Let us imagine the Moscow-Soci route dotted with these power stations. Along the whole length of the route there will only be four or five. The aircraft will no longer need a drop of fuel, and will thus be able to carry double the number of passengers and double the load; it will fly faster than the modern plane and will take off from Moscow on a power beam. Then the beams from Tula, Orlov, Charkov, etc., will pick it up. It will be a kind of overhead wireless bus.

'Could the power ray become a weapon? Very improbable. Because it would be very easy to refract above a glossy surface just as the solar rays refract in a mirror. But it will enable us to sweep meteorites from the path of a space ship.

'To manoeuvre a space ship travelling at six miles per second would be a very difficult task. The encounter of such a ship with a small meteorite of terrific velocity would be like a balloon meeting an armour-piercing shell.

'This is how I imagine we shall solve the astronaut's problem of meteorites: the ship will constantly sweep the space round it. If a meteorite is spotted at a dangerous distance the mechanism of the electronic calculator will go into action. It will be able to say immediately whether the ship is in danger of a collision. If a collision is inevitable a powerful beam of energy will be directed at the intruder. It will be difficult in space to find bodies with a refractory surface. Under the action of the power beam the substance of the meteorite will be heated and will evaporate into tiny fragments. The ship will merely run into a cloud of steam instead of this cosmic shell. And all this will take place in a fraction of a second.'

CHAPTER 16

The Revolution in Intellectual Work

A CENTURY and a half ago neither calculating machines nor the science of electronics from which they developed existed. There existed only a dream: the creation of a machine capable of executing work which only the most marvellous machine of all could do – the brain. It is said that Napoleon, a passionate lover of chess, sat down to play with a mechanical opponent. The creator of this machine – quite remarkable for the period – demonstrated his invention to the emperor. It was a marvellous assembly of wheels, levers, and cogs enclosed in a large metal box. Despite his skill and bravura the emperor was soundly beaten by his mechanical opponent.

The secret of the automatic chess player was soon discovered. A dwarf was hidden among the cogs. He was a superb player. Unfortunately, during a match a fire broke out and he had to make a precipitous exit from his hiding place.

In our days automatic chess-playing machines really exist. They say that one of them managed to draw a game with the great chess player, Rescevski. They are electronic calculating machines, in contrast to the machines built to replace human labour, such as tractors and harvesters, bulldozers and rolling mills, which mechanize only man's physical labour. To discuss the future of these marvellous machines we visited the great expert on the subject, Professor Sergei Alexeivich Lebedyev, head of the Institute for Automation and calculating machines at the Soviet Academy of Science.

'It is almost impossible to talk of the future of our branch of science,' Lebedyev began. 'We have hardly had time to take stock or to put into practice a host of interesting possibilities which the electronic brains have given us today. There are so many examples that I really don't know which would interest you most.

'The first of these machines was created in 1945. In twelve years, with the aid of this machine, our mathematicians have been able to solve the most complicated problems. How can I explain this to you by taking a simple example? Every student knows that it takes about three minutes to solve equations with two unknown quantities and that an equation with 200 unknowns would require years to solve. In practice a man who had the courage to complete this task would have to work on the sum with pencil and paper day and night for twelve years! The machine, on the contrary, can solve these equations in less than an hour. In one hour it can compose the logarithm tables upon which in the old days mathematicians spent many decades.

'But even these speeds no longer satisfy mathematicians and physicists engaged in internuclear research. The machines already solve the most difficult equations in private industry. On the other hand modern science is constantly faced with problems which cannot be solved unless we speed up the tempo of the calculating machines.

'At the outset,' Sergei Alexeivich went on, 'the speed of solution attained a mere thousand operations per second. Today we have reached tens of thousands and in the near future machines will be capable of doing several hundred thousand and perhaps millions of operations per second. Let us take building for example. We wish to determine what form and what slope we have to give the banks of a canal so that they do not collapse. Calculations have been made. But after the builders have progressed a few hundred yards the soil changes; the previous calculations no longer hold good. Thus, because of a slight mathematical miscalculation, time, labour, and money is wasted in the digging. The calculating machine will afford perfect accuracy.

'Meteorologists have begun to give far more accurate weather forecasts since they have started using machines. Within an hour they can now predict the weather for the whole of the Soviet Union for the following day.

'Electronic aids enable mathematicians to test swiftly a large number of variants of a problem and to select the best. In this way they can determine the most convenient shape for an aircraft wing, a jet engine nozzle, or the blades of a turbine.

'Many machines are already functioning today throughout Russia and in the Calculating Centres. The current Five Year Plan provides for a great use of electronic machines. Particular attention must be paid to production. Electronic brains will be able to direct various assemblies, conveyor belt plant, and perhaps even whole factories. They will help men to carry out the most complicated technical processes needing constant supervision, to calculate many factors involved and give the immediate solution.

'Chemists need to create, to synthesize, a certain substance with specific characteristics. What are to be the components of the new material? The machine can answer this question. It will analyse the properties of scores of substances, will compare the various characteristics and data, and finally suggest a choice of two or three to be used as a basis.

'The most intelligent and industrious apprentice will be unable to reproduce with precision the motions of a master craftsman who for many years has studied all the details of working metal. Will the art of this skilled man die with him? No! We can record, copy each of his movements, and on the basis of these notes the electronic tool will be able to work without the participation of man. Automatic tools of this nature already exist.

'Any detail, even the most complex, can be described in a series of mathematical formulae. On the basis of these formulae the electronic machine will ensure that the tool carries out the detail with precision. It is difficult to say how statistics would have fared had they not been aided by the new machines. Automation of the technical side of statistics spares a host of clerks the tiring work of making their own calculation.

'The radio industry plans an annual production of ten million television and radio sets. Each machine has several thousand parts. These are mass-produced by specialized industries. The calculating machine can work out rapidly the production plan for each part.'

Professor S. A. Lebedyev spoke laconically and with authority. Each of his ideas conjured up marvellous images for us.

At a certain place in Transcarpathia or in a small Ukrainian village a house bears the following sign: 'Biblio-transmission'. Boys and girls enter. They are obviously secondary-school pupils and students from institutes of technology. They are all very punctual. They cannot afford to be late. In cabins not unlike telephone booths glow the bluish screens of television sets. Here is one group of students. They are admirers of the great Taras Scevcenko and are reading attentively the biographical details of this inventor on the screen. In the next booth the screen is covered with columns of formulae and an invisible speaker helps the future technician to master the rudiments of higher mathematics. This morning the teacher advised his pupil to attend a mathematical lesson with the aid of biblio-transmission and gave him a chit on which was written: 'Dear Bibliotechnician, please allow this student to attend the mathematical lecture transmitted from Lvow. Will you be good enough to record the transmission so that it will be available in future?'

But this is a miracle! Who is this bibliotechnician? How can he have the lesson transmitted from Lvow?

Bibliotransmission covers all manner of literary, historical, and scientific information and is carried out on orders with the aid of television.

To listen to the transmission no radio is necessary; all that is needed is a simple pick-up. Thousands of pick-ups are connected with the transmitters. The bibliotransmission network functions in the same manner.

There are few books in the village library. There are many more in the city of Lvow and a vast number at Kiev and Moscow. The great libraries house thousands of volumes and the range of subjects is so great that for information purposes it is necessary to have hundreds of consultant bibliographers. But even the specialist cannot keep in his head all the various ideas which man has accumulated down the ages and has to spend days on end consulting catalogues, checking thousands of lists before he finds what he wants.

Man has to cram his memory with a great deal of scientific information. He will be helped by the 'memory' of the electronic information machines. At his request the machine will select from the slots and set in motion the magnetophonic matrix on which both the words and images are reproduced. Thus a great quantity of information is classified in the film libraries of the book centre and the electronic machines 'remember' and select any subject required from millions of magnetic tapes and microfilm. They transmit the mathematical lesson to the Transcarpathian village, or lecture the students on the life of Scevcenko. This is the function of the village bibliotechnician. He helps the readers and his television audience, obeys the requests for information and directs it immediately to the respective libraries, controlling the screens. The bibliotechnician is the librarian of the future.

We are at an international conference. A machine no larger than a desk immediately translates into every language the speech of the delegate irrespective of the language he speaks. It is possible to build these machines today. The problem is speed. We can already see the path we must take to speed up their performance. Today we use special all-purpose machines which can change their method of calculation. But they are large and complicated. We have specialized apparatus for solving specific problems which work much faster. This is on the lines of the specialization we find in industry.

Calculating machines will relieve man of a great deal of hard work and will free his brain from monotonous mathematical work.

It is depressing to have to admit that productivity in the workshops has been increased in this century by 1,400 per cent whereas in office work it has so far only increased by 40 per cent. But in the next few years this liability will be overcome. A great revolution will take place in the output of intellectual work.

The machine will help man and in some respects may surpass him, but it will never entirely replace him. Human intelligence will always be superior to that of his robot son. Only man can suggest the most economical way of solving a problem and propound to the machine a new and improved programme. He can increase the speed, accuracy, and productivity of the machines, simplify their construction, and reduce their size. Whereas in the first electronic machines there were 18,000 thermionic valves, today the number has decreased to 4,000, and within a few years there will be none: the valves will have been replaced by semi-conductors or transistors.

'The employment of these new machines, the reorganization of man's mental work by their results,' concluded Professor Lebedyev, 'can only be compared with the stage in history in which, during each century, mechanical work is introduced to replace manual labour. Machines will revolutionize material work. Today we are entering a revolutionary phase in intellectual work.'

CHAPTER 17

Man Will Kindle an Artificial Sun

'WE should like to dream a little, to talk of what will happen in the twenty-first century,' we said, as we entered the small laboratory of Professor Georgi Ilyich Babat, who is famous for his work in industrial application of high-frequency current.

The laboratory was full of radio apparatus, of strange adaptations, steel and copper wires coiled like ropes aboard ship.

'Be careful not to touch any of the gear,' warned Babat.

Looking round carefully to avoid inadvertently sitting on some electric chair we took out our notebooks.

It is difficult to decide which is the more important in Babat's life, his scientific or his literary activities. He has made important discoveries and written many interesting books and articles of a scientific nature. His plans include tempering steel with high-frequency current, building stone-paved roads by treating the soil with this current, high-frequency boring, transport, refuelling of aircraft by a power ray, and constructing an electric sun. As a source of original ideas he is inexhaustible. One of his novels, entitled *Magnetron*, has been recently published.

But today we are visiting Babat the scientist and not Babat the literary man.

'You mention dreams,' he said, 'but it is a question of dreams with a solid and rational basis, not of fantastic plans and baseless Utopias. The scientist and the inventor with their creative ideas can project themselves into the future, but always with their feet firmly on the ground. In the history of technology there have been brilliant discoveries which were very short lived. For example Jablocnikov's candle glowed brilliantly and went out equally quickly, while Lodighin's incandescent lamp still shines today. Many creative ideas are maturing in science, but not all of them will bear fruit.

'The seeds must be selected, the ideas which will really flower tomorrow. This is the problem of the research worker and the inventor. To find them, to determine which will really be capable of development in the next ten decades, is no simple matter. This is perhaps why certain science fiction writers are so pathetic.

'You say that you are interested in the problems of high-frequency transport and its future. The principle is simple. If you pass alternating high-frequency current through an overhead cable or a subterranean conduit, it acts several hundred times quicker than in ordinary electric wires, and round the cables a swift alternating electromagnetic field forms from which power can be extracted to drive the high-frequency "transport vehicle". Electric signals in the form of radio waves are captured by the aerial of a simple radio set, but their power is only used for collection and not for a further use of energy. In the high-frequency transport apparatus we have the same radio set with a receiving aerial which houses the machine. In the latter is generated the electric current which, after a series of transformations, turns the electric motor.

'Modern radiotechnics have developed to the point where the flight of aircraft and rockets can be directed by a mechanical radio apparatus. This will be the brain of the machine. Experiments with machines driven by high frequency built in Russia up to 1943, therefore during the war, have shown that high frequency constitutes not only the brain but also the physical strength of the machine.

'In order that wireless-fed electric motors can be adapted to the machines we must as a start create a superabundance of electric power. That is why high-frequency transport will not be developed for another fifteen or twenty years.

'To equip the roads and main highways for high-frequency transport we have to place a cable beneath the macadam or the concrete at a depth of not less than eighteen inches and build electric stations along the road. This will be the costliest and most difficult task. On the main railway lines (Moscow-Sinferopoli, Moscow-Kuibyschev, etc.) it is not at the moment convenient to place such cables.

'Other systems which hold out great promise will vie with high-frequency current. You realize that nuclear submarines which can travel great distances are already at sea; an atomic icebreaker has been built and plans are on the designing board for atomic aircraft which will be able to fly several times round the world without landing to refuel. But a nuclear motor cannot be assembled on a light vehicle. Therefore instead of nuclear car engines (piston engines will have disappeared by the end of the century) we shall have to use in and about the city high-frequency transport. Trucks and mobile cars run on high frequency will be used for interdepartmental transport in factories.

'In the past few years a new aid to high-frequency transport has been invented and developed – the semi-conductor. I do not know whether you have heard the term "sleeping lines"? These are underground cables which normally do not consume power. As soon as a high-frequency vehicle appears on the road the "sleeping lines" spring to life, recharge the machine, and then return to sleep to economize electric power. One of these lines can work for several decades without being replaced. It will consume far less energy than our street-lighting systems. And this will be made possible by a new feeding process through crystal semi-conductors.

'There was an age when a concrete road was considered a luxury. Today it is a commonplace. In the twenty-first century concrete roads without high-frequency cables will be inconceivable. Electric cables will be placed under the new road just as today, when the foundations of a building are being laid, the water supply, drains, and electricity are laid on simultaneously. When building the roads with slabs of concrete every 50, 100, or perhaps every 500 yards a semi-conductor system will be laid consisting of two or three crystals of a volume of some cubic millimetres. This will constitute a simple automatic relay which whenever necessary will "awaken" the high-frequency cable. This network will have its "nervous system" of cells which are at present hand-made. Today the semi-conductor relay costs less than an electronic valve. Of the two semi-conductor materials to be found in nature – germanium and silicon – the latter is the commoner. For semi-conductor apparatus, however, a very pure silicon is needed. To obtain this has so far been a long and difficult operation because pure silicon costs a million times more than the sand from which it is extracted. In electronic computers, too, the cells are made of pure silicon. As opposed to the human brain, which is formed mainly of carbon, the electric brain, the electric "nervous system", is of silicon. Considering the latest progress in nuclear technics it would sometimes appear as though electrotechnics had already exhausted their development potential. But this is by no means the case. Electricity is and will remain the most varied and most convenient source of energy. Its enormous possibilities will be exploited to the full. The most interesting prospects are those which concern the application of high-frequency current.

'At the beginning of the twentieth century high-frequency current had not yet been used. It only began with the invention of radio. But the radio transmitting stations use less than one per cent of all the electric energy generated. The importance of high-frequency power began to be appreciated after the First World War. Towards 1930 electrotechnics developed by the melting and tempering of metals with high-frequency current and machines consuming up to 100 kilowatts of energy appeared. It was found profitable to smelt and temper by this method grades of steel of the purest chemical composition. Today high-frequency machines exist which consume thousands of kilowatts. They are used in all branches of industry. Nevertheless today high frequency is still a luxury; it is only employed for the most delicate constructions. The constant development of industry makes more and more demands and electric power is still lacking. This is why metallurgy has not yet become electrometallurgy.

'We must begin to think of building semi-conductor machines, perfected computers; but the youth of today, our future engineers and technicians, must realize that unless we improve the existing electric machines no progress will be possible in the field of electrotechnics. Here is something to think about: how can we increase the power of machines, how can we raise the load ratio, how can we use to greater advantage this or that machine, what type of current shall we use in each particular case? In other words, we must skilfully exploit the possibilities afforded by electricity, which is constantly progressing and which will constitute the basis of industry. High-frequency power will take first place in electrotechnics in the next score or so of years.

'But why is high frequency so important? It enables us to change with ease every characteristic of current – tension, strength, and volume. For example, in railway electrification, it is far more useful to use maximum tension. But this means that the trains must be equipped with very complicated machinery to transform the current. High frequency will save the situation. It will represent the links of a new chain in the fuelling of air liners and the motors of an electric train.

'But maybe I am a little too optimistic,' the professor added with a smile. 'I have only told you things which everyone knows. Now let us discuss a few of the fantastic aspects of the use of high frequency. The hot rays of the sun which have always inspired the poets have a very much more prosaic significance for the physicist. He sees in them the flow of electromagnetic oscillations, one of the aspects of electric energy most susceptible to changes – nine volts per centimetre.' The scientist pointed to the machines which register the voltage of solar light in the full midday sun. 'While the high-frequency generator can give hundreds and thousands of volts per centimetre, the sun provides two kilowatts of energy per square metre. A high-frequency generator allows us to concentrate on one square metre the power of several thousand kilometres. These rays are more terrible than those of the Martians described in H. G. Wells's novel. The most interesting thing, however, is that in recent experiments it has been possible to build industrial machines capable of pulverizing the hardest mountains. Do we need, for example, to make a tunnel through the Pamirs or the Himalayas? Do we need to build a road across the mountains from India to Siberia? A small fifty-ton tank with a radiation grill sets to work. It approaches the mountain and attacks the solid rock faces with its ray.

'Heated to a very high temperature, the rock begins to split from the heat and is finally reduced to fragments because the water contained in it is transformed into steam. The temperature is raised and the rock melts and flows in a river of lava while the ray continues to advance. This high-frequency "mole", which tunnels the rock, works automatically. The human operator is a long way away from the scene.

'In the history of the human race, the development of science may be compared with a constantly rising spiral. It is not the first time that man has employed fire at high temperatures to destroy gigantic blocks of stone. This method was already current in Ancient Egypt. Later he had recourse to mechanical boring. To dig shafts he began to use explosives. Today science has returned once more to the flame. A fiery jet of gas is directed on the stone from the nozzle of a jet motor.

'Other experiments have been made: a steel tube is filled with oxygen and the nozzle is ignited. Tunnelling can also be done by this incandescent tube. But one of the most interesting methods of tunnelling through a mountain is by high-frequency current. At the present-day level of production of electric energy and despite the cost, this method promises wonderful results, and a group of scientists in one of the Soviet Mining Institutes is busy on this problem.

'The production of high-frequency electric power in the twenty-first century will probably reach from ten to twenty-five per cent of the total electricity production. It will replace the direct current by a quarter of the total consumption.

'In 1930, at the Svetlana Works in Leningrad, the idea of using high-frequency generators to temper steel was put into practice for the first time. The Americans have exploited our idea and have outstripped us in the number of plants generating more than a million kilowatts. But we shall soon be in a position to catch them up and to surpass them in the practical exploitation of high-frequency current.

'Towards the end of this century metal cutting will be almost entirely replaced by stamped metals. Everything from huge crates to the smallest tins, cubes, and cogs will be made of metal fused with high-frequency current.

'The people of Moscow will be faced with a magic spectacle in thirty to forty years' time. I think that this might happen on New Year's Eve of the year A.D. 2000 when man will enter the third millennium. An artificial sun created by man and carried to a height of twelve to fifteen miles will illuminate Moscow and its environs with its rays. Millions of kilowatts and the whole output of the Stalingrad Power Station on the Volga will be consumed to give the Capital this gigantic street lamp. To be precise it will be neither a lamp nor a searchlight mounting an aerostat. . . .

'High-frequency electromagnetic rays will cross above the Red Square, burning incandescent molecules of nitrogen and oxygen. The nitrogen oxide which forms in the flame of the artificial sun will fall upon the earth like the rain and the wind in the guise of valuable fertilizers.'

We asked Georgi Ilyich Babat to tell us how the idea of kindling a high-frequency 'sun' was born. He looked quite pleased. The boldest fantasies, the most ambitious dreams need practical support. Experiments are the scientist's support.

Babat picked up a large book bound in rawhide.

'This is the diary I kept during the War,' he said.

Turning over a few pages he found the notes of interest to us. They were written in the sad days of the late autumn 1941. People worked for days on end without a break. Many slept in the laboratory. But the city still had electric light and it was therefore possible to carry out experiments. The engineer Babat was in a hurry to complete the work he had begun. He left the laboratory less often than the others. It was actually during these experiments that the metal 'petals' of his machine gave off a tremulous flame like a flower about to open. The tiny sun lit the scientist's laboratory. Babat fed this apparatus not with direct but with a modulated current.

In more simple terms, he did it by means of an interposed radio set. Subjected to the oscillations of the electric current, the flame began to tremble, alternately bright and dim – a kind of membrane which made the surrounding air oscillate and generate sound waves.

Babat spoke to us of the other uses of high frequency. He described to us the telephone of the twenty-first century which with one single net will cover the whole globe. A man will be able to speak to a friend living in the other hemisphere. There will no longer be the need for huge telephone exchanges which today have a limited number of lines. Research mechanics will now be using everlasting semi-conductor apparatus. A semi-conductor commutator for every few hundred subscribers will be no larger than a shoe box. Automatic amplifiers will allow us to speak in comfort to South America and to call up directly or indirectly any house phone in any country. (The network will have an infinite number of channels.) The high-frequency system in practice will allow us to have as many lines as exchanges.

CHAPTER 18

A New Window on the Universe

VITALI LASEREVICH GINZBURG, the brilliant scientist, known above all by his work in the field of radio-astronomy, began his account not with the results obtained by astronomers but with problems of physics.

'Physics is the mother of radio-astronomy,' he said. 'If we are to speak of the future, our number one problem is that of thermo-nuclear radiation. Humanity will learn not only to explode hydrogen bombs, but also to regulate the power produced by thermo-nuclear reactions in the furnaces of the atomic power stations. The achievement of a slow hydrogen reaction and of the synthesis of eternal light nuclear atoms will solve the problem of fuel.

'Now let us take problem number two. This is bound up with astronomy and many other ancillary sciences. The first to approach the solution of this particular problem were the Soviet scientists with their 1957 experiments – I mean the launching of the first Sputnik. In fifty years' time I am convinced that a number of Sputniks will be speeding round the earth at various altitudes. They will circumnavigate the globe in an hour or an hour and a half. The greater the altitude of the Sputnik the farther away from the earth will be its orbit and in consequence its movement on the horizon will appear slower. Of particular interest will be a Sputnik about 6½ earth radii distant from the centre of the earth, in other words, 25,000 miles. If it is launched from the Equator in the same direction as the earth's rotation, and if it attains an angular rotation speed equal to that of the earth, an observer on the Equator will see the Sputnik hanging motionless in the sky.

'This will be extremely useful for uninterrupted observation. Sputniks will shortly be used for various scientific and technical ends, for meteorological observations, television transmissions, etc. The Sputnik will also help us to verify the general theory of relativity. Time, with regard to a fast-speeding object, may perhaps travel more slowly. This can be verified with a single experiment.

'The sun and the stars send to the earth ultra-violet and X-rays. But the earth's atmosphere, like a filter, captures both of these rays. The instruments in a Sputnik will also examine radiation in its "pure" aspect.

'It is important that astronomers should know the luminosity of the night sky and the total luminosity of the stars. But try to determine with any accuracy how much light is radiated in a night sky, with the atmosphere rising to a height of some hundred miles! In order to succeed we must go up higher, and this is precisely what the scientist of the future will do, when scores of Sputniks will be in orbit at various points in the upper strata of the atmosphere.

'For thousands of years men have looked up at the immensity of the Universe through a narrow "optic window". The moment has come to use the larger "radio window". Through this, new and greater horizons will be opened up.

'Our radio-astronomers have hardly set out on this new path. Radio-astronomy is one of the younger sciences of our age; it only started to develop after the Second World War. But even in its brief lifetime we have obtained through the "radio window of transparency" a mass of information about the Universe which would not be possible by any other means. Radio-astronomy sees what is invisible even to the most powerful telescopes.

'Let us examine the sun. It is a compact gaseous sphere enveloped by an incandescent atmosphere, the solar corona. Its temperature reaches millions of degrees. The luminosity of the corona is relative, representing only a hundredth part of the sun's total luminosity. The corona itself emits light comparable with a full moon. With the normal optic methods it can only be studied during total solar eclipse, when the blinding disc of the sun is covered. Observation is very constricted because eclipses last for only a few minutes. This does not apply to radio-astronomics. The entire solar radiation leaves the corona on metre waves. We have learned that the atmosphere of the sun extends to our nearest star. This colossal atmosphere occupies a tenth part of the distance between the sun and the earth.

'By studying the radiation of our galaxy, that gigantic stellar system, astronomers are convinced that it is surrounded by an enormous gaseous cloud which can be detected in radio waves but which, on the other hand, is invisible with the ordinary telescope. Let us imagine that we have on earth a special instrument to see radio waves. This is not as fantastic as it sounds because radar possesses such "visual power". Through this instrument the whole world around us will appear completely unrecognizable. Above all, we shall overcome the blinding luminosity of the sun.

'Optical spectrum analyses show that the temperature of the sun's surface is 6,000° C. and that the radiation from the solar corona corresponds to a temperature of one or two million degrees. Such temperatures exist inside the sun, this cosmic thermo-nuclear furnace.

'At night we can see in the sky the Milky Way, a luminous ribbon formed of a myriad stars. By day, as a result of the sun's light, the stars are "extinguished" and we can no longer see them. A being endowed with radio power could see the stars as well by day as by night. Before him would open the black vitals of the Universe, the so-called radio stars, the sources of radiation invisible to the naked eye.

'In certain radio rays some of the stars are luminous like the sun, although they are tens of thousands of light years away.

'But the sun will not lose as a result of the many radio beacons in the sky. Do you know why? Because while all the other stars shine regularly and with uniformity, the sun has its own particular luminosity. The radio luminosity of the sun oscillates very violently while in the optic pitch its light hardly changes. Only occasionally do sun spots increase in size. The intensity of solar radiation can increase considerably, possibly ten thousand times, and then the radio-telescopes are disturbed. But after a few minutes everything reverts to normal.

'We have spoken of radio visibility as though it were a dream. But I believe that in the twenty-first century man will acquire a complete and acute radio vision. Let us imagine that we are in an observatory of the future at a powerful radio-telescope. From a diagram you select a code number and on an enormous screen will appear the radio map of the particular zone of the sun you require. On the other hand, you may decide to observe Cassiopeia, the star of the year 369 – or to be more accurate what remains of it, because in that year it exploded. The jets of gas caused by the explosion have formed a nebula. Or again you search for a luminous radio star in the constellation of Cygnus, or for two giants which have collided. Powerful radio radiation produced by this collision allows us to follow that cosmic disaster 280 million light years away.

'Certainly I do not intend to use the word "disaster" in its empirical sense. We must not consider stars which collide or fall on one another and the radio signals which arrive from them as an echo of these cosmic encounters. The stars in the galaxies are tremendous distances apart. The distance between the nearest can be measured in scores of light years. Collisions are very rare if not impossible. On the other hand, collisions between gaseous cloud and cosmic dust do occur. Their mutual penetration is accompanied by a host of collisions and reciprocal action on the part of their particles. It is precisely these which constitute the source of the radiation which reaches us.

'This grandiose natural phenomenon was discovered with the aid of a radio-telescope. This instrument will probably allow us in future to distinguish and examine all the details of these collisions.

'Optical telescopes have reached the limit of their capacity. They cannot see farther than two million light years. The radio-telescope will observe far more distant nebulae. The lens of the modern optical telescope is more than fifteen feet in diameter. But even greater lenses will be built. A telescope with a lens of about eighteen feet is being planned in Russia. But we still have the possibility of a better use of existing telescopes. Optical electronic apparatus increases the scope of the telescope to the point where the fifteen foot lens in normal conditions gives an enlargement which could be obtained by one of thirty-foot diameter. Radio-telescopes are not yet able to give the same clear picture as the optical variety. To arrive at the same degree of precision, and of details furnished by the ordinary telescope with a fifteen-foot lens, it would be necessary to build a radio-telescope with an aerial 5,000 miles high. This is impossible and would serve no useful purpose. The single tall radio aerial can be replaced by a chain or by a network of aerials connected with the observatory and between themselves by radio transmission. Such a chain, for example, could extend from Moscow to Gorki. Some of these chains could gradually be connected to a radio-telescope network similar to the high-frequency electric grid. In this way we shall be able to build a giant radio-telescope. Towards the beginning of the next century I think that we shall be in a position to build one which will cover the whole of Europe.

'Let us now return to our twenty-first century observatory where we shall find the host of signals picked up by aerials distributed throughout the country. On the operator's screen we shall see a radio picture of the sun, beneath which is a plate reading "1 metre". The sun is huge, luminous, and clear. You press a button and a radio wave of sixty cm. begins to function. The sun on the screen is now reduced in size. This means that the sixty cm. waves are radiated from distances farther away from the sun's centre. The operator will tune in to a ten-metre wave and the picture of the sun will be tripled in size. With the aid of this telescope the radio-astronomer will not only calculate the intensity and the constitution of the radio waves emitted by the heavenly bodies but also discover their source.

'Observation of the radio radiation which reaches us from space is not our sole preoccupation. The radio-astronomer will not only pick up the waves which reach us, but will direct on to other planets radio beams which, like sensitive fingers, will explore their surfaces. At the end of the Second World War both in Hungary and in the United States the first radar signals were sent to the moon and the echo received on earth.

'Today, a gigantic radio-telescope with a metal mirror-aerial of 210 feet is being built in Manchester. For a more detailed survey of the moon even greater telescopes will be made. By changing the wave length we can get a section of the atmosphere of some planet such as Venus, Mars, or Jupiter.

'Radio-astronomical methods will allow us not only to observe the future of our galaxy but also to learn its past. We live in an expanding Universe. Five billion years ago the average density of the substance of the Universe was considerably larger than it is today. What is the nature and what are the laws of this expansion? How did galaxies and single stars form? I believe that at the beginning of the twenty-first century we shall know the answers to these questions.'

CHAPTER 19

Travel of the Future

LET us imagine that some Rip van Winkle fell asleep in 1909 and suddenly woke up in the year 1959. What extraordinary changes would meet his eye! The marvel of electric lights! In his days, of course, he had seen a similar type of illumination in the houses of the rich but he could never have imagined that this would become so widespread. And then the marvel of radio! A small box with a green eye which winks magically, with a small bulb lighting up a scale on which are printed the names of so many cities. Is this not perhaps a miracle? In the room he listens to music which at this moment is coming from La Scala in Milan. And another marvellous box, the television! A screen on which clear-cut pictures live, suffer, and speak. The unbreakable glass on the desk is made of an unknown material – plastic. The writing materials, the ash tray, and the calendar holder are of the same material. And the fountain pen which has replaced the quill and the steel pen will arouse the keenest interest in this Edwardian who suddenly arrived among us.

He does not stay very long in his hotel room. He sets out on a stroll through the city and during his journey his enthusiasm will be aroused by all the innovations he sees. The macadam of the streets and the squares is the first thing which will catch the eye of this man who was accustomed to cobbles. The neon lights will dazzle him. Are these the fires of some aurora borealis plucked from the sky and imprisoned in small glass tubes, he wonders. Entering a shop he finds shoes of artificial leather, buttons of plastic, crêpe-soled shoes, electric refrigerators and cleaners, a host of objects which did not exist fifty years ago and which today everyone possesses. He will go to a cinema and perhaps see Cinerama. What a marvellous development of the modest discovery of the Lumière brothers.

He will fly over Russia in the roomy cabin of a TU 104 jet aircraft. Man has conquered the skies, our unusual guest will think.

But could the man of 1909 have foreseen all that now bewilders him in 1959? Many of them, perhaps, but not all. Undoubtedly he could foresee the development of aviation, the appearance of the talkies and coloured films, the changes and improvements in motor cars, but how could he have foreseen television? Fifty years ago the long series of basic ideas, discoveries, and inventions without which long-distance transmission of moving pictures is impossible, did not exist. In those days, such a suggestion would have seemed madness. Just as today it would seem utter madness to think that we shall be able to transmit objects or living beings thousands of miles by radio.

All the ideas in this book, however, are based on knowledge already acquired.

We began our travels in the study of Professor Vassili Vassilievich Zvonkov of the Russian Academy of Science. We were interested in the problem of transport in the twenty-first century. It was early morning. 'The best time for work,' said the scientist. 'I have got up early all my life and I believe that compared with the others I gain two or three hours in every twenty-four. Figure out how much that means in a lifetime!'

He laughed, but then his eyes grew cold and serious. Picking up a bundle of scientific journals he began: 'Envy is a very harmful sentiment which shortens one's life. Nevertheless, I envy the people who will live in fifty years' time and who will be able to enjoy all the fruits of science and technology. We have become accustomed to using marvellous machines until we take their services for granted. Machines light and heat our apartments, allow us to speak to each other at a distance of hundred of miles, saving us fatigue. My speciality is transport vehicles, and I am proud to say that their development has already reached a very high level.

'I have just been to America and returned to Europe in one of the largest and most luxurious ships, the *Queen Mary*. This transatlantic liner is registered at 81,000 BRT and has engines developing 200,000 h.p., equal to the power of a large electric power station. But let us imagine this huge ship caught in a tempest. It will wallow and roll until it seems that it must be smashed to pieces. And yet this giant ship is stable and can travel at about twenty knots. It can cross the Atlantic in five days. How long shall we need for this trip? In fifty years' time I think only one day. To achieve this the design of ships will have to change radically. The resistance met with by a ship at sea is of two kinds – the resistance of the water and that of the air. Today, the former is the greater. How can this be reduced? Perhaps by raising the hull out of the water during navigation. Everyone has seen how a seaplane leaps over the crests of the waves like a flying fish. The keel is as broad and flat as a ski. Nevertheless, we cannot yet build flying boats even a tenth the size of the *Queen Mary*. There would be a number of insurmountable technical difficulties.

'In recent years attention has been drawn to ships with submarine wings. When the ship is travelling, these underwater wings, like the wings of an aeroplane, suddenly become subject to lift. They remain under water but raise the hull of the vessel. Craft of this type, only on a smaller scale, already sail on the Volga. So far, however, none of them can carry great loads.

'The problem of decreasing water resistance without lifting the ship out of the water can be solved by radically changing the shape of the hull. This shape has been unchanged since antiquity. If, on the other hand, we could cut the body of the ship in two and instal the engines in the centre the water resistance would diminish considerably. I have tried this out with a model. On the basis of my calculations the traction would increase by forty-five per cent. The wake increases in the bows and to stern, and represents the energy recovered by the engine.

'Had the *Queen Mary* been built on this principle, the ship could have crossed the Atlantic not in five but in three days. Our children will probably travel in this type of ship.

'I do not think I am incorrect in assuming that the passenger liners at the turn of the century will be submarines. The speed of the ship will certainly be greatly diminished but the inconvenience of storms will be eliminated. It will be much more comfortable and profitable to travel under water. Submarine and passenger ships will be able to sail beneath the polar ice and thus shorten their distance between continents. It is interesting to speculate on the type of engine which will be used in the ocean-going ships of the future. They will, of course, have atomic engines. But in what consists the great advantage of atomic energy as a substitute for coal and oil? Above all, the fact that the energy produced by the fission of uranium is enormous. Two pounds of uranium 235, in its capacity to generate heat, is the equivalent of two trainloads of anthracite. This means that in the ships of the future there will be no boiler room. In modern ships the boilers take up a third of the ship's space.

'The problem of using atomic reactors in ships has already been solved. Calculations made by the Soviet Academy of Science indicate that the loading capacity of ships equipped with atomic motors – even though they are still in the initial stage – is from twenty to thirty per cent greater than ships equipped with steam turbines. Freights in atomic ships will be greatly lowered compared with steam ships. Ocean-going cargo vessels will be able to carry 100,000 and possibly 200,000 tons. To reach speeds in the realm of fifty to sixty knots such ships will have some parts submerged and others above the water. For passenger transport, however, it will be more economical to use jet aircraft.

'Now let us speak of long-distance land transport such as the railway. The gauge of Russian railways is 1,524 mm., but this is no longer satisfactory. Gauges of 9–15 ft will allow us to build roomier trucks, to use 40–50,000 h.p. locomotives, and to reach speeds of 150–200 m.p.h. The problem of equipping trains with atomic power will also be solved. As we know, biological protection hinders us today from using atomic locomotives on our railways. Plans for such engines are on the designing-boards of other nations and advanced students in our technical institutes are already studying this subject. Shall we, perhaps, have to resort to a far wider gauge? It will probably be necessary to build very wide gauge continental tracks, but this will be in the next century or perhaps in 100–150 years' time.

'In recent years tube transport has increased. There is reason to believe that this type of transport will be developed for heavy loads – oil products, petrol, cement, corn, flour, etc. And now a few words on city transport. In the past ten years, all over the world, parking problems have arisen and this has reduced the usefulness of the motor car. I saw this phenomenon at its worst in New York. In certain districts there were such jams that traffic was brought to a standstill. The cars drove at walking pace. Traffic was one-way because of the parked cars. In these conditions it is impossible to utilize fast motor transport even if the horse-power is increased. Private parking becomes an insuperable obstacle. It is my considered opinion that by the end of this century no cars will be allowed to circulate in the big cities. The owners will have to leave them in the suburbs and use public transport.

'The extra-urban cars of the future, equipped with turbojets, will develop a speed of 150–200 m.p.h. This will only happen, of course, once the great motorways have been built. At the main crossroads and side junctions there will be flyovers at different levels. What will be the innovations in city transport? Probably moving pavements and helicopters. Imagine parallel horizontal ribands moving at different speeds – 12, 25, and 60 m.p.h. These lines will travel along all the streets in both directions. To enter and pass from one to the other will be as easy as it is to use a moving stairway in the underground.

'For convenience on these moving pavements there will be at intervals easy chairs, benches, automatic machines selling sweets, ices, chocolate, and cigarettes. (Incidentally, I believe that we shall have given up the habit of inhaling the fumes of dried weed through a paper tube. It will be a thing of the past, an anachronism.)

'I believe that the first moving pavements will be on roads with pedestrian crossings, today the craziest and most dangerous invention. These moving pavements are a certainty. Starting on one or two streets, they will then extend in a well-organized network to serve the whole city centre. Buses and overhead railways will only be used in the suburbs as the trams are today. Next the suburbs will have a network of moving pavements which will eventually replace the modern suburban lines.

'Now let us go on to air transport. I have travelled a great deal and have had many opportunities of flying. My last trip in a four-engined Superconstellation across the Atlantic from Paris to New York took seventeen hours. It was a very comfortable first-class aircraft which rocked far less than the *Queen Mary*. But only once have I really enjoyed an air trip and that was in a TU 104 – a magnificent machine which is the forerunner of the aircraft of the future. The flight from Prague to Moscow, at 30,000 feet, took less than 2½ hours without the slightest jolt. We virtually could not feel that we were moving. A truly admirable voyage.

'Atomic propulsion, passenger flights through the ionosphere at an altitude of 45–60,000 feet, the increase of speed to 3–5,000 m.p.h. will be quite normal in aviation. Admittedly I have only touched on the general and most important problems. The future cannot be foreseen in detail and we can only indicate the direction progress will take.'

CHAPTER 20

Moscow in the Twenty-First Century

WE were five in the room – two journalists, a typist, the director of Moscow Town Planning, Nikolai Fiodorovich Yevstratov, and the map of Moscow of the future. We guessed that this interview would be of the greatest interest. Yevstratov spoke slowly, weighing every sentence, trying to be as concise as possible and not to appear to us as a visionary.

'Cities change their faces very slowly,' he began. 'I think that if Balzac today could wander about the streets of Paris, in which his heroes lived a hundred years ago, he would have no need to make any topographical corrections in the text of his novels. In the course of centuries, not even the face of Moscow has changed very much.

'I should like to give a typical example in the history of Russian town building. Peter the Great, foreseeing an attack by Charles XII at the beginning of the eighteenth century (1702–6), fortified the Kremlin and the Kitai-Gorod. As we know, Charles launched his attack on the Ukraine instead of on Moscow, and Peter defeated him at the Battle of Poltava. The Moscow fortifications encumbered the main streets. Nearly all the present-day Red Square, the Sverdlov Square, and the Teatralni Way were covered by fortifications. Nevertheless, so lazy were the town builders that these ramparts survived for more than a hundred years, and were only demolished in 1823.

'Very much the opposite occurs in Moscow today. The capital has changed its face in the last forty years. I asked a man who had visited the capital before the Revolution to sum up the changes which had taken place. Since he was a poet, he replied with a lyrical comparison:

'"What can I say of a woman I loved and have not seen for forty years? I look at her old wrinkled face and only here and there can I catch a glimpse of her erstwhile beauty. I have not seen Moscow for forty years, and now looking at her rejuvenation and beauty I can only distinguish in occasional places the old wrinkles I know so well."

'Moscow has become unrecognizable in the last forty years, and it will develop even more rapidly in the next ten to fifteen years. Today the city covers 17,500 acres; in the future, it will cover more than 30,000. While about seventy per cent of the population live within the confines of the Kamer-Kollejski fortifications, seventy-five per cent will eventually live beyond these walls.'

We looked at the future map of Moscow which covered an entire wall. We recognized the bends of the Moscova river, the breadth of the circular roads by the well-known Kremlin polygon in the centre of the city. It had, however, spread out in all directions, absorbing all the suburbs. Nearly a third of the New Moscow was covered with green and blue patches representing the parks and hydro-electric reservoirs, arteries radiating from the centre. Yevstratov took a metal stick and pointed out various details of the new town planning.

'In the next five years Moscow will expand to the south-west behind the University. The most modern districts will be the Ceremuska, part of the Barovskaia, and the village of Sil. The city boundaries will be extended to the north in the Chimki zone, in the river harbour zone, and in the suburbs of Chovrino, and we shall start to build the new Masilow district. In the following years Kunzevo will become one of the best districts in Moscow. And what will be the population of this great city? Today it is 4,850,000 and this figure will not rise very much in the future – possibly to the 5,000,000 mark. This is the maximum population figure which can ensure the necessary personnel for industry and public works. Speaking of Moscow of the future, I must mention the new towns between forty and fifty miles outside the Capital. One of these satellite towns will be Yachroma where there is a hydro-electric plant and another will be Krasniaia-Pachra.

'Moscow will be a marvellous garden city. In the next few years we shall start work on a great park in the south-west zone.

Here will also be built a majestic building, the Pantheon, where the most famous sons of our country will be buried. The little turbid Setgun river will be transformed into a number of small, bright-blue lakes. The Tarta district, Stroghinov, will also be rebuilt. As you know, it takes many years to lay out a park with trees. When the English talk of their green lawns, they say, "you must water them every morning and mow them every evening and go on doing so for a hundred years". In the streets of Moscow today we are able to transplant fully grown trees and saplings. There will be no lack of greenery. We shall have broad, tree-lined highways and flyovers where these cross the circular roads. Cars will drive over and under bridges.

'Today the parks of Moscow cover an area of seven square miles. We plan to double this. In this green belt will spring up new holiday villages, new hospitals, many child welfare clinics and youth camps, kindergartens and playgrounds.

'Another characteristic of Moscow of the future: each zone will be completely different from the next and differently organized. In the residential quarters we shall have schools, playgrounds and kindergartens for children, large stores and sports stadiums; in the industrial zones, broad streets and alternate lines of communication, including small gauge railways.

'All this is the work of the next ten or fifteen years. But let us see now what a street in Moscow will look like in the far distant future, in the twenty-first century.

'The air will be fresh and redolent of the fields and woods. This will not only be due to the great extension of gardens and parks. A car will pass without a sound, like a bird without wings. It will not leave behind any blue exhaust gas because transport will be electrified. The cars will be run on high-frequency current from underground cables. The same current will be used in winter for cleaning the streets and sweeping away the snow. It will also be the best method of heating the streets and pavements. As soon as the snow falls it will melt immediately. This will not be such a costly and uneconomical undertaking. Today in Moscow we spend almost as much on sweeping the snow from the streets as we spend on petrol. The new system will cost far, far less.

'The old factory and power station chimneys with their noxious fumes will be a thing of the past. Industry will no longer need fuel because all the power will be provided by electric current. And, finally, in the kitchens, gas, so popular with the Muscovites in the first half of the twentieth century, will be replaced by electricity.

'Let us imagine that we are on the Lungomoscova in fifty years' time. The river bed will be clear and we shall be able to count all the pebbles. Shoals of gold and silver fish will sport among the algae. In Moscow there will be no more sewers for the detritus will be drained on the spot and utilized. The purified sewage will be enriched with oxygen before being led off into the river.

'As twilight descends the streets will be brightly lit with electric lights. The daylight lamps will not be suspended from wires or on standards; they will be attached to the façades of the houses, serving as a decorative effect and providing a constant illumination as bright as day.

'On the squares will shine the scarlet letter "M" indicating the underground stations. From the forty miles of 1955, the underground network will be increased to 150 miles. In front of each station exit will be found a plan of the whole network which will cover every district in Moscow. But we shall also have inter-terminal lines joining the northern railway with the Kazan and Kursk line and with the Kiev line. Travellers who descend at Moscow will find themselves in the centre of the city, while those in transit will not have the bother of driving from one station to the other at opposite ends of the capital.

'Most beautiful of all will be the façades of the four- or five-storey houses partly hidden by trees and shrubs. Let us enter one of these houses and ask permission to visit an apartment. Brightly lit, air-conditioned rooms with huge windows. Radiators have been replaced by heating in the walls and ceilings. This automatically increases the radius of heat while the cost is substantially reduced. The radiator system produces dust and dirt, making the air in the rooms unhealthy. The water in the heated pipes will reach a maximum temperature of 60–70° and there will be neither dust nor filth.

'In the kitchen there is no more refuse to attract the mice. A pulverizing machine disintegrates all the house refuse and disposes of it in a conduit. If we go out on the flat roof we shall see a curious winged machine. It is an air taxi.

'All the taxis in the twenty-first century will be airborne. They start up with a slight whirr and change into a kind of shining umbrella.' It is already dark when we take off to fly above our marvellous Capital of the future. The town plan which we saw in Yevstratov's study seems to have materialized all over the vast expanse of Moscow, which is as bright as day. In the distance, resplendent in the light of an artificial sun, looms the monument of the founder of our State, Vladimir Ilyich Lenin.

CHAPTER 21

The Motor Car of A.D. 2007

'YOU want to go to Ensk?' asked engineer Dolmatovski. 'Let me take you by car. I have the latest 2007 model.' We approached a silver machine with very small wheels parked outside in the street. The tapered back resembled the tail unit of an aircraft. The harmonious horizontal and vertical lines of the coachwork were broken here and there by slanting lines. The streamlined body had neither windows nor doors and the whole vehicle was made of a strange material.

'This is not metal,' said the engineer, pointing to the coachwork, 'it is a special plastic material with very interesting properties. But have a look inside. Get in!' The engineer did not raise a finger. Hardly had he pronounced the words 'get in' when a sliding panel opened on one side of the car. We got in. From inside the bodywork seemed transparent. A small dashboard with a few buttons amidships. All the rotating seats were adjustable. Dolmatovski settled himself in his seat and turned to us in the back. Without looking round he said calmly: 'Route S.W. Destination Ensk.' We did not feel the motor start or get under way. After a minute this driverless machine was speeding along the grey riband of the road at 150 miles an hour. Then the speedometer needle registered even more. The lights from the houses which sped past made our heads swim. The engineer touched one of the knobs and the sides became opaque. But the light which continued to filter in was as bright as before.

'Now let us go back 100 years,' said the engineer, 'to the period when the first automobiles fired our imagination by their novelty. Can you compare those slow, noisy monsters with this comfortable house on wheels? As you see, this car has comfort which you will not find even in a luxury flat – radio, adjustable lighting and heating, cigar lighter, and air conditioning. Even in the latest models of the first half of the twentieth century fifty per cent of the car space was taken up by the engine, the radiator, and the boot, leaving only half the space for the occupants.

'Many years of research were needed to reduce the encumbrance of the mechanical parts. Today they occupy not more than twenty per cent of the whole car, and this figure includes the electronic gear for, as you saw, the car is now controlled by orders given by the driver. This equipment takes the machine by the shortest route in the direction ordered without the least intervention. This allows us to read during the journey, listen to the radio, look at television, or talk to our friends as we are doing now.

'Naturally the creation of such cars was closely bound up with the building of roads suited to this purpose. Radar apparatus was fitted to cars for the first time in 1956: this was in constant contact with the milestones on the road. The photo-elements follow signals given in morse. Whereas today the milestones, the morse signals, and the road itself have all been calculated for the traffic of these machines. There is nothing strange about this. The road of today ensures absolute safety, is always dry, cleans and dries itself. It drives the car and provides the driving power.

'You will be interested in the motor of this machine. Naturally it is no longer the internal combustion engine of the twentieth century. Piston engines were replaced by gas turbines forty years ago. After this there was some competition from atomic motors, but today we use only cars driven by electricity. Beneath the road are electric cables supplying high-frequency current. The energy of the electromagnetic field which develops in the cable is captured by an aerial beneath the car. Actually, the underground cable can be compared with the aerial of a transmitter, while the motor acts as the receiving set. High-frequency power picked up by this receiver is transformed into current which drives the motor, which is coupled directly to the wheels. The "radio motor" in our car is equipped with semi-conductor crystal valves and, therefore, takes up little space.

'Now let us consider the speed. The car designers of 1957 were already capable of building fast cars. Nevertheless, for land transport the economical speed in practice cannot be less than 150 m.p.h. We meet with two forms of resistance – that of the wheels and that of the air. The wheel resistance of a car moving over a tarred surface at 150 to 200 m.p.h. is so great that motor travel is no longer comfortable. It is far more convenient to fly because the fuel and power consumption are less. Therefore, we use the car for short journeys and the aeroplane for the long ones. Is it possible to build flying motor cars? Personally, I find this an embarrassing question. To build a car capable of flying you need complicated couplings which would put up the price. The driving and flying qualities would not be ideal. A flying hybrid would be inferior to both the motor car and the aircraft. Flying cars could only be used for certain specific purposes.

'It is true that experiments have been made recently with so-called gliding cars. The essence of the plan is as follows. Beneath the body of the car is installed a special apparatus which generates an electric current in the surface below the car. The reciprocal action of the electromagnetic fields of this current and of the machine itself lifts it fifteen to twenty inches from the ground and the car proceeds at this altitude as though it were airborne.'

Our machine pulled up gently near an aluminium lighted arch which spanned the street. We read: 'ENSK' on the archway, and a little beneath it the word which seems to have survived down the centuries and which is the symbol of Russian hospitality: Welcome! We got out.

'Let us leave it here and take a driverless taxi,' said Dolmatovski. 'There are plenty of them and they are at the disposal of every citizen. No, there's no danger! All cars, as you have seen, are driven automatically and the machine will not carry out orders unless it is admissible.'

We passed beneath the aluminium arch and into the city.

CHAPTER 22

The School of the Future

'LET us visit a twenty-first century school,' said the Director of Public Works and Buildings, Georgi Alexandrovich Gradov. Ensk, where we arrived, is a medium-sized city and its schools are no better or worse than elsewhere.

'Apropos of the city,' put in his deputy, Alexandr Lev Chenevich Pojarski, 'Ensk is the realization of one of man's pet dreams, a garden city. Here you will find every facility for work and for play. Amongst the foliage little two-storey houses have been built; the high-frequency buses and cars leave not the slightest cloud of exhaust gas and move silently along the tree-lined roads. At the crossings, half hidden by greenery, twinkle the neon signs of the public buildings, libraries, and clubs. The large factories and industrial buildings are separated from the residential quarters by a green belt. No trace of dust in the air, no noise, nothing but the scent of jasmine and lilac. There is no need to leave this city for a holiday, especially as the rest homes and hospitals are also in this rural environment.'

In the hall outside the director's study engineers and architects were at work designing other houses and other public buildings.

'We have not yet solved the problems of schools,' one of the architects told us. 'The classes are still being held in two sessions. We lack hospitals, kindergartens, and dwelling houses. But the government is giving priority to the solution of this building problem. We must remember that a new town cannot be built in a day. Even taking into account the rapid development and the level reached in building techniques it will be at least ten years before we can satisfy all our needs.

'We are thinking today of what we shall see in fifty years' time. By then we shall have real garden cities with the schools and factories all surrounded by vegetation. We shall have clusters of small two- or three-storey houses surrounded by enclosed gardens of roses and acacias.'

We entered an imaginary school of the future.

On a wall in the main hall was the time-table for all the classes. 'Today,' the director told us, 'the standard of culture and physical development has developed to a point where we begin to educate children at the age of five to shorten the gap between the kindergarten and school. School has changed and is no longer separated from home life. The final certificate does not so much signify a good preparation in general culture but guarantees that the student has a profession at his fingertips – automation, telecontrolled mining, or atomic-power-station operator, electronic computer mechanic, etc.'

'The main professions of the twenty-first century,' one of us cried.

'Yes, technical instruction is given in this school. Let us go to the other wing and you will see our science classes. The polytechnic system of teaching has already justified itself.'

This wing of the school was complete in itself. No models or simplifications . . . Everything was done here as in a real industry. Our guide took us into the sports section. Here, in huge well-lit halls, almost entirely of glass, we saw the equipment for almost every type of sport and game. One hall was devoted to hockey and another to skating, with a full size ice rink. In another hall there was a large swimming pool. The park outside the physical culture building was merely an extension housing tennis and basket ball courts, football fields, and running tracks. We had no time to visit them all because our guide kept leading us on farther into the gardens and orchards, which were divided into small sections where the students could make experiments. From here we went into the actual classrooms.

Noiseless floors and brightly lit lecture halls . . . with walls of special glass set in a porous structure. By allowing a great deal of light to enter, the glass protects the interior from direct solar rays. For rainy, winter days there was a special illuminated ceiling of opaque glass.

Each pupil had a desk to himself and the school doctor periodically checked the benches because it is easy to ruin a young, growing body with a desk unsuited to its stature. The furniture was of aluminium alloy, light wood, and plastic. The classrooms were square-shaped with the desks placed in a semicircle as in an amphitheatre, so that the pupils could see better. The air was extraordinarily pure as all the rooms were automatically air-conditioned.

In all the entrances to the classrooms we had barely opened the door when blue transparent lamps went on and were extinguished as soon as we crossed the threshold. They had a very important function because the rays from these lamps killed bacteria. Our clothes, bodies, and shoes were thoroughly sterilized by these rays, which were quite harmless to a human being. No microbe from the street can enter the school.

'Moreover,' explained the director, who had noticed our surprise, 'these lamps carry out a thorough weekly disinfection of the school premises. As a result, during the eight years I have been working here, I have only had one pupil suffering with a cold and two cases of influenza.

'The amount of knowledge gathered by mankind continues to increase. Science and technology become more and more complicated and specialized to the point where it has become increasingly difficult to absorb so many ideas. The teachers are faced with a problem – to find methods of study which, with a minimum waste of time, will allow the pupil to assimilate the maximum amount of information, data, and ideas. One of these methods is by visual demonstration, and the greatest aid in this respect is the cinema. In each class popular scientific films in sound and colour are shown and with models the teachers demonstrate complex chemical reactions.

'The polytechnic classrooms and the laboratories have television sets in addition to the cinema and models. The students visit the various branches of the outside establishment dealing with their speciality and then try out the experiments for themselves in the classroom. Sometimes, in the course of studying a certain problem, the teacher uses a television receiver connected to an X-ray apparatus; then, for example, the vitals of a compressor stamping out the coachwork of a car can be projected on a large screen in colour.

'The boarding schools where the children receive a completely scientific education are spread all over the country. At an early age they have the possibility of developing their inclinations and talents. Apart from the laboratories and the classrooms, they have at their disposal an artists' studio, music rooms, photographic laboratories, and rooms with all types of toys and aquariums. The parents participate in the education of the child, and since they have a four-hour working day they can devote plenty of time to their children.

'The children grow up healthy and handsome. In each school there is a huge hall for physical culture, each class having its own physical culture instructor. Every two or four schools have a swimming pool and sports ground. There are not forty pupils in a class as in the old days but thirty. Teachers believe that to get the best results the class should be reduced to twenty-five or even to twenty pupils.'

Next we visited the living quarters. The small children's rooms had four or five beds and a great many picture books and toys. They were the same dolls and animals as in the old days but executed in far better taste. The slightly older children had constructional sets of the greatest variety and ingenuity. Above their beds hung models of space ships. Obviously the dream of space travel had not lost its charm, although in the meantime it had become a reality. The older children lived two in a room – with an abundance of books, cameras, easels for designing and painting. What a full life our grandchildren, those born on the eve of the twenty-first century, are living in their schools!

We went out into the street and looked at the whole of the school from the outside. No trace of contrived luxury, giving it the appearance of a school for rich children. Everything is designed to offer the maximum comfort, space, light, and air to its small guests. We took our leave of the school director and were once more in the streets of our twenty-first-century city.

At a street corner ahead of us we caught sight of the dome of a huge 2,000-seat cinema. Its façade was of aluminium and bronze alloy with plastic and was ablaze with neon lights. Near the cinema was a huge hall covered with a glass roof and glass walls – the winter garden. In its quiet corners the visitor could read a book, sit in an armchair near a fountain, watch the television, or listen to the radio. Exotic plants – palms, olives and laurels, and lianas clinging on a special framework – gladdening the eye with their evergreen, creating an ideal surrounding for relaxation before the performance began. There was also a café, a restaurant, and a library. The whole arrangement of the building invited the visitor to spend a few hours in pleasant surroundings, to rest and learn something of interest.

In the city the architects have used fluorescent colours to decorate the façades of public buildings. By night they all sparkle. Social centre buildings in particular looked like multicoloured fairy palaces.

In the evening the picturesque corners of the parks come to life. Chinese lanterns illuminate the trees and flowers, underwater floodlights transform the fountains into fantastic aquariums. By day, in these public parks with their beds of red poppies and lilies, the fountains play. How pleasant it is on a warm day to wander about under the trees.

The architect, Gradov, told us how the heating problem had been solved. In the ceilings between floors and in the walls are installed batteries with semi-conductor elements. These batteries have a curious property. If the current enters them from one direction they heat, and from the opposite direction they cool. The current changes automatically according to the inside temperature, either heating or cooling to the required temperature.

'What a marvel this winter garden is when the temperature outside is 30° below zero,' said the architect. 'The snow melts on the transparent walls made of triple blocks of glass from between which the air has been pumped. Inside, magnolias flourish. Let me tell you another interesting detail about the inhabitants of this city. They never wear winter clothes as they did in the old days. No furs, no fur caps, no fur-lined boots or mufflers. If they have to work in the open air or for sport they use special apparel. There is no need to put on a fur on leaving an air-conditioned house to go for a drive in a car which has the same equipment.

'The speed and the low cost of building, the speed of transport (electric trains and fast taxis travel at 150 m.p.h.) have allowed us to transfer the residential zones to picturesque spots far from the big city and the industrial belt. Satellite towns have been built with special private dwellings and public buildings. The façades of these buildings have been stripped of the old rococo decoration which no longer satisfies our tastes. Today, architectural forms are both simple and functional.

'Humanity has giant reserves of energy and the economic problem of house fuel no longer exists. The dwellings have broad windows, verandas, and balconies which can be covered with glass roofs in case of rain or snow. The external appearance of the houses is, as a result, very picturesque. Pliable trellis, walls of plastic in tasteful shades, allow the architect plenty of scope for originality despite the standardization of the building trade.

'Multiple machines, which at the same time dig a trench, lay drainpipes made of a mixture of glass and fibre and fill in the earth; in this way the water system, the sewers, and the heating become a simple and quick matter.

'A new and important element has entered town building – plastic and other chemically produced materials. The buildings themselves are made of solid perspex or new light flexible metals with a high insulating coefficient. The modern, compared with the old brick house is five to ten times "lighter". Mass production has been introduced in the building trade and the component parts are made in factories using automation. One of these concerns produces in a single year as many houses as were built in Moscow in 1957 by the work of scores of factories and workshops.

'The solution of the housing shortage problem, the abundance of hotels throughout the country, allow us today to move about wherever we like. Men have started to have freedom of movement and often change their domicile. This has improved the tenor of life, has been beneficial to the nervous system, the general health, and above all to the intellectual development of the workers. Some of them from force of habit still go to the "dachas" every spring. They load their plastic prefabs on a truck or helicopter and go to the mountains, the sea, or any place which happens to please them. The three- or four-roomed villa can be dismantled and assembled within two hours without the use of outside labour or equipment. Others, on the contrary, prefer to remain with friends and go to floating islands (which can house from 3 to 5,000 people) ideal for a holiday at the seaside. These little floating towns move slowly along the shore, visiting the most picturesque gulfs. On these islands, as on land, there is a transportable theatre which can easily be transformed into a circus or a stadium.'

Gradov now broached another very interesting topic – the cinema of the future.

'If I were to relate the marvels of the cinema of the near future you would have difficulty in believing my words. But Professor E. M. Goldovsky is better equipped than I to give you details. He is the greatest living cinematograph technician.'

CHAPTER 23

Magnetic and Film Photography

'LET us visit a cinema of the future,' said Goldovsky. We crossed the hall and entered the projection room. 'You will find several very disparate apparatuses, not only in shape but in the principle of their function. The one on the left is the television receiver used for the projection on a gigantic screen of sporting events, mass meetings, and other occasions of general interest. With this cineteleviser it is possible to project a film which we do not have in stock.

'The projection is on a small screen of a cathode ray tube and is then enlarged on to the large screen. The first models were built as early as 1950. The equipment you see in the centre and to the right is for projecting ordinary reels. Here is the film spool of the central apparatus. On this you can see the single shots with the aid of a magnifying lens. But the film in the equipment on the right is a reddish-grey absolutely opaque riband. It resembles the riband of a tape recorder and this is precisely what it is. The principle of this registration is quite simple. The picture is subdivided into a large number of separate elements, as in teletransmission, but instead of passing into the ether the signal from each spot is registered on the magnetic ribands. The projector deciphers the signals in the form of small luminous points; they are reconstructed on the screen and become a picture. The system of magnetic recording of pictures is used in the twenty-first century on as large a scale as was magnetic sound-recording fifty years ago.

'But let us look at the cine-camera in the centre. The first thing that will surprise you on the film is the lack of marginal perforations which serve to focus the details on the screen. This particular camera has magnetic focusing by means of the magnetic dots on both sides of the film. These give greater accuracy than the old-fashioned method.'

We returned to the present. The professor's account became scientific and concise, full of figures and technical terms.

'As you know, photography was invented in the year 1839. To obtain a photograph in those days a man had to stand for half an hour motionless and rigid in one pose with the same expression on his face. By the second half of the twentieth century the time needed to take a photograph was reduced approximately fifty million times. Today an exposure of 1/25000th of a second is possible – a fraction of time imperceptible to the human senses. The basic fact which has ensured such a telescoping of exposure time is the increased sensitivity of the film to light. This sensitivity has increased 20,000 times – and still it is not enough. People who have visited a film studio know how difficult it is for actors to be "shot", surrounded as they are by a host of spotlights and subjected to an implacable stream of blinding light and heat. The quest to increase the sensitivity of film will, therefore, be continued. Cameramen and photographers of the twenty-first century will no longer have to bother about lighting effects: they will be done by incandescent spotlights and flash equipment. The shots will be taken with normal lighting and if necessary even at dusk.

'Today, the photographer is bound to the precision of his exposure, to the exact timing of the shot which has to be accurately measured. He must not over- or under-expose. This is due to the fact that the "sensitive width" is very narrow and allows neither too long an exposure nor too great a reduction of light. Photographic material is being tried which will relieve the photographer from having to bother about exposure, and he will be sure of the quality of his picture whatever the conditions. Another grave inconvenience at present is the granulation of the emulsion strip. You must have seen greatly enlarged photographs by photograms at reduced speed. On these you see the single grains, out of the spots of which the picture is formed. These spots blur the details and the granulosity of the film limits the enlargement potential. We shall succeed in reducing this granulosity and thus be able to use film of ever smaller format. In this way we shall be able to make really efficient mini-cameras. I think that at the beginning of the next century cameras will be the size of a wristwatch. With photoelectric cells the necessary aperture will be established and also the length of the exposure dependent upon the light. It is difficult for an amateur to take good photographs today – particularly in colour. In future a fine photograph will be taken by a child with no experience and there will be no need to control the temperature during development. In colour photography the triple developing process in which each film strip reacts to one colour will no longer be used but will be replaced by a single film in which will be present tiny granules of all the three strips usually employed.

'Will photographic processes also change a great deal? It is quite possible that the chemical photography of today will be replaced by electro-photography. This is still in its embryo stage, in the same stage which chemical photography found itself many years ago, but it will certainly be developed and perfected. Electro-photography or, more simply, dry photography is one of the applications of semi-conductors which will make a deep mark on science and life in the twenty-first century. The process involved is as follows: on a small metallic strip a layer of selenium is placed. If the selenium is charged positively and then exposed to the light the charge under the action of light will be transferred to the underlying metal. The strip is placed in the camera and the picture is taken on it. The electric charge penetrates the selenium in illuminated dots and reaches the strip where the light cannot pass. Thus you obtain a kind of electric picture in the form of various loads, proportionate to the intensity of the exposure to light at the various points. The strip is then covered with a fine powdered negative charge of colour. By applying sensitized paper to this the photograph will be obtained. We already have special paper for such photography.

'Electro-photography has a number of advantages. The same material, the same strip, can be used several times; the photograph can be obtained much more swiftly, in fact in a second. The copying process is dry. Another advantage is the fact that with this system the film remains immune to radioactivity. I believe that the cinema will also use this type of photography and that special electro-cinecameras will be built.

'To conclude the conversation on cinematic and photographic materials of the future, I want to say something about the changes which will take place in the making of film, especially with regard to the base on which the layer of emulsion is placed. Today it has a series of defects: insufficient resistance to damp, a tendency to become brittle, etc. We shall certainly have film impossible to deform and far more solid. It will be more elastic and narrower so that a full length film will be contained in a single reel, while once loaded the camera will take hundreds of pictures.

'Let us visit a large cinema of the next century. It is broader than it is long. A high ceiling, air conditioning, and very comfortable seats . . . no resemblance to the cinemas of today – small, windowless, airless boxes with the seats jammed together in closely packed rows. In the cinema of the future, on hot days one will feel a delicious fresh air, and in winter intimacy and warmth. An enormous fifty-yard wide screen will cover half the width of the hall. In place of the one projection room there will be several with synchronized apparatus. The lights round the roof go out slowly and for a moment the hall remains in darkness until the screen lights up. Now we can see what use the various projection units serve. The picture over the whole area of the screen is composed of various beams of light, projected from a series of cameras placed at different points. The picture changes continually in dimension, extending over the whole screen for crowd scenes and panoramas and becoming smaller and smaller when the sequences represent interiors or close-ups. The combined effect of the fusion of various synchronized projectors is so perfect that the audience seem to be participating in the film.'

Goldovsky explained that the 'effect of participation' will have been realized.

CHAPTER 24

Siberia Seen from a Space Ship

SIBERIA! Few people know this marvellous country, impossible to imagine in all its vastness, with its incredible wealth and natural variety. Of the total reserves of natural wealth in our country, Siberia produces ninety per cent of the water power, eighty per cent of the coal, sixty per cent of the iron ore, ninety per cent of the non-ferrous metals, seventy per cent of the timber, and eighty per cent of the arable land. In Siberia we have everything we need to develop a great and powerful industry. There are already indications that what has not yet been discovered will be found in the future.

For instance, recently large deposits of a natural fuel, a kind of oleiferous gas, were discovered. This means that oil will also be found. Towards the year 2007, the Siberian oil reserves will form the most important part of the whole oil output of the Soviet Union.

We had a chat with Leonid Vasilievich Pustovalov, vice-president of the Soviet Research Institute.

'You ask me what the overall picture of Siberia will be in the year 2007. Well, let us project our minds forward to that period, take tickets on a model super-speed atomic aircraft, and fly over some of the regions of southern Siberia.

'Here, on the endless plain, near the white dams of the river-fed hydro-electric stations, among the huge deposits of iron ore and non-ferrous metals, on the expansive coal fields and in forest never explored by the foot of man, will spring up in the future great urban centres and a host of workers and factory towns. Siberia will have a network of technical colleges, universities, and its own Academy of Science. Huge buildings and ultra-modern factories, houses and rest homes will be built.

'The climate of southern Siberia is harsh in winter and torrid in summer – a dry, healthy climate, well suited to the development of agriculture. Here there is no danger of fever and many other diseases from which the inhabitants of the damp tropical zones suffer.'

We flew over this marvellous country. Below us appeared, only to disappear behind the far horizon, cities, villages, and railway lines linking the industrial zones. The reservoirs of the power stations gleamed, vying in grandeur with the lakes. From the window of our aircraft we could not see all the details, but we could clearly recognize some of the main geographical and economic features of the Siberia of the year 2007.

Now we were flying over the region of Krasnoyarsk at a great altitude. The expression 'a bird's-eye view' no longer had any significance. We were flying at an altitude which no bird could ever have reached. Our route was from west to east. We flew over the great dams on the River Angara which has its source in Lake Baikal. Near the reservoirs on the bank of this river (a few years ago it was swift and full of rapids) in an almost uninterrupted chain stood the new Siberian cities, which will not be found on the maps of the twentieth century, new factories, buildings, and villages. Here in particular were concentrated industries demanding great quantities of cheap electric power: aluminium and magnesium works, electro-metallurgical concerns, and factories producing chemical fertilizers. This was the newest and the largest industrial centre of our country. It will use not only the cheap hydro-electric power but also the coal from one of the largest coal-bearing basins in the world, the Tungus.

Flying over the Krasnoyarsk region we remembered the controversy that raged among the Soviet experts in the middle of the twentieth century. Some insisted that industrial development in this region would arrive with the use of its hydro-electric resources. Others, however, championed the inexhaustible reserves of the local fuel. The men who held the latter point of view recognized that power from hydro-electric stations is much cheaper than that generated from thermic power stations. But this general rule need not apply to the

Krasnoyarsk region where thermo-electric energy by its cheapness could vie with the energy of Stalingrad or of the Volgskaya power station. This is because here the coal is found at the surface or is merely covered with a very small layer of soil. The coal can easily be extracted with an excavator, loaded at little cost, and transported direct to the power station.

Siberia, country of miracles, which cannot be compared with any other land! Its possibilities are immense, just as those twentieth-century experts thought when they stressed the need for developing industry in the region of Krasnoyarsk by exploiting this cheap local thermic energy.

But now, beneath the silver wings of our atomic plane, we saw a picture which proved that neither of these two schools of thought had been adopted. The ideal solution of this problem which had bothered the specialists of those days was found to be in a rational use of both hydro-electric and thermo-electric energy. From above we saw that apart from the huge hydro-electric stations dating from the beginning of the twenty-first century, the region of Krasnoyarsk had a vast network of thermo-electric stations running on local fuel sufficient to supply all the nearby industrial plant. This avoided the expense of transmitting electric power great distances, from the power station to the consumer.

Our plane veered slightly to the north and carried us to the Yaput territory. Below we could see the basin of the Viliui River. Fifty years ago this was a wild and hostile region. Today it is the diamond centre of the Soviet Union, with great buildings, a host of villages, arterial and side roads. The diamonds are found in a primary bed and are of the finest quality, similar to those mined at Kimberley. Tubular pipes are bored almost vertically into the bowels of the earth.

We recalled the long and complicated story of the discovery of diamond-bearing deposits in Russia. Isolated diamonds were found by chance in the Urals at the end of 1829. Further researches, which proved fruitless, were carried out by the German naturalists Alexander Humboldt and his companion Gustav Rose. At the beginning of the nineteenth century the two men made a great voyage across the central Urals as far as Altai near the Chinese border. The Tsarist government subsidized their search for diamonds but the prospecting at that period was of an amateur nature and produced no results. The Soviet Government however organized systematic prospecting over vast areas. Whole regions of Russia were explored in the quest for diamonds but for a long time the geologists failed in their tasks. Not until 1950, in the bed of the Viliui River, were the first diamond deposits found. After this many were discovered in quick succession.

At the beginning of the twenty-first century in Siberia the largest diamond bed was found, surpassing the output of Yakutsk. The days when the South African diamond magnates made the laws and fixed a price control throughout the world were now past, as the Siberian diamond mines successfully competed with their South African rivals both in quality and quantity.

By switching on a powerful television set we could see near the Viliui a few crescent-shaped excavations below. Each of these depressions was a diamond mine. From here the whole of Soviet industry is supplied with the precious stones which are used for working the hardest metals, for boring particularly hard rock, and for precision instruments.

Our aircraft sped to the east. We crossed the splendid basin of the great Lena River, which skirts the wild Verkhoyansk mountain range. From this great altitude we could barely see certain dots, which were in reality oil derricks. This new oil bearing region of Yakutsk has been called the 'Third Baku'. Fifty years ago the geologists of Yakusia discovered the first great bed of oleiferous gas which initiated oil prospecting on a large scale. Now, at the beginning of the twenty-first century, the whole of Siberia is supplied by the 'Third Baku'.

From here run the oil pipelines, and the gas conduits supply the Siberian cities, works, and factories. Along the main Siberian railway lines we no longer saw tankers transporting oil from west to east.

Our aircraft turned abruptly to the south. Soon we were above the capital of Yakusia, the city of Yakutsk, and a few minutes later over the mining region of Aldansk, now famous for its gold. The whole region had been completely transformed and from above we could see the coal mines spread out all over it.

This carboniferous basin is one of the miracles of Siberia. In the other coal-bearing basins the most precious type of coal – that transformable into coke and thus ideal for the metallurgical industry – constitutes the minor part. Here, in the South Yakutsk, explored for the first time by Soviet geologists in the middle of the twentieth century, the major part of the whole basin is of coal transformable into coke.

Near the coalfields are large iron deposits. It is unique that these two raw materials, essential for metallurgy, iron, and coke, are found next to each other, with the resultant lowering of transport costs.

On our flight over the mining zone of Aldansk we saw not only coal and iron mines but also metallurgical establishments. In this way it is no longer necessary to send to eastern Siberia pig iron from the western regions of the Soviet Union.

There is also an important metallurgy centre at Nerchinsky, a long way off our air route. It is near Chitin in the Katorga zone where the Tsars built their forced-labour camps. Today it is a flourishing region with a highly developed iron and non-ferrous metal industry. The coal for metallurgical purposes is carried on electrified railways which have recently been built, linking this area with South Yakut coalfields.

After flying over the Stanovoi range we saw the silver ribbon of the Amur River gleaming in the sun.

Twenty-five years ago the Amur and its Chinese and Soviet tributaries – Zeya, Bureya, Seldenga, Sungary, and others – caused enormous damage by their disastrous floods. It was necessary to harness and regulate the vast indomitable energy of these streams.

Since then the Amur and its main tributaries have been changed. Their precipitous course, regulated by a series of dams, has been tamed and bows to the will of man. Land reclamation has considerably increased the area of fertile land. Nor does the Amur region suffer from the periodical floods which occurred in the past. Near the dams are powerful hydro-electric stations which supply the new Soviet and Chinese industrial concerns with cheap energy.

With the taming of the Amur, traffic and transport on this river have been greatly developed.

The River Sungary, one of the largest tributaries of the Amur, is connected by a canal with the Liaokhe River. Across this Sungary–Liaokhe Canal system, passenger and cargo vessels can sail from Amur direct to the Yellow Sea, which never freezes, and from there to all the Chinese ports. In addition to this across the Ussary and Lake Khanka the Amur is also connected with the ice-free Gulf of Peter the Great near Vladivostok. And finally, a little farther to the south, the Amur is linked with the Tartar gulf.

In this way the great Amur has four outlets to the open sea and is being transformed into a vast transport artery. The days are past when the Amur served solely to mark the frontier between the Soviet Union and China. Today it lives up to its name, for Amur in Chinese means 'Peace'. The Amur no longer divides in hostility the Soviet Union and the Chinese People's Republic. The Chinese at one time called the Amur 'Chei-Lung-Sian', which means the 'River of the Black Dragon', but today it has been renamed the 'River of the Electric Dragon'.

Once more our aircraft changed course to the north, and now we were flying over the sea of Okhotsk. Here was Kamchatka, the peninsula of active volcanoes and hot springs, the last stage of our imaginary journey. The fishing industry, as in the old days, remains the main economic activity of Kamchatka. But the technique of fishing and the equipment of the canning factories along the riverbank has made enormous progress. In addition to the fishing industry the extraction of combustible minerals in the last few years of the twentieth century has greatly developed and a rich mining industry has sprung up. Deposits of rare materials such as mercury, arsenic, and antimony have been discovered and mined.

From the window of our aircraft, which now started to descend, we had a clear view of the volcanoes of Kamchatka whose craters are still active, betraying the subterranean activity of the fiery magma. The hot springs originate from this magma. Their thermic energy today is used not only to cure sick people but also in industry. Nearly all the power used in Kamchatka today is obtained from this free subterranean heat. Volcanic activity, the main feature of this and the neighbouring islands, was at one time a continuous source of trouble. Today it has been harnessed in the service of man and affords the inhabitants the cheapest power in the whole of the Soviet Union.

Our aircraft started to land. Observations from great altitudes at great speed must inevitably be fragmentary and incomplete, but they can nevertheless give an impression of the enormous progress which has taken place in the eastern regions of the Soviet Union.

CHAPTER 25

The Creators of Nature

THE Bible says that God created the earth and everything within it, on the surface and, in fact, the surrounding Universe – including the sun, and the moon, and the host of stars. It is difficult to say what occurs on the numerous planets and stars; we do not know enough of the conditions reigning there, nor whether they are inhabited. But as regards the earth, any engineer will maintain that our planet was planned haphazardly.

The construction of the earth can be criticized from various points of view. The useful minerals are not logically distributed. Whole continents and countries are rich in minerals whilst others are very poor. It would be much more pleasant if iron deposits could be found next to coke, aluminium next to sources of cheap power, and Chilean nitrates, the most important of the fertilizers, near agricultural zones. But, alas, as a rule this is not so.

Probably even in the future, man will have to adapt his own strength to this badly organized planning just as he adapts himself to a house which is not to his own taste. When a man intends to live for a long time in a house, he modifies it according to his own desires, putting up partitions and making new doors. This is what we must do to our communal house, the earth – transform it to our own needs and our own taste. Of course, not everything can be changed because even in the largest house certain elements cannot be changed.

From time immemorial there have existed irrigation systems which transformed enormous expanses of desert into flowering country. Is not this a transformation of Nature?

A network of canals unites seas and oceans and separates continents – Africa from Asia Minor, South from North America. Does not man, by building these canals, change the face of the planet?

A particularly great development has taken place in the transformation of Nature in Russia. The River Volga has become a series of lakes. Immense reservoirs have been built on the Dnieper, the Don, the Yenisei, the Ob, and the Kama. Irrigation channels penetrate deeply into the most arid lands. Enormous forests extend over regions lashed by hot winds. We have changed the map of our country, its climate, its animal and vegetable world – everything, in fact, which can be called Nature.

But these are only the first steps, the first tentative steps to penetrate into the mechanism of the planet and to change its eternal path. In the future, as man's power increases, this transforming activity will develop even further. Then perhaps we shall make a strict list of the constructional faults of our world just as technical commissions can catalogue the defects of a certain machine. Already, today, we can envisage some of the items on this long list.

The inhabitable land occupies less than thirty per cent of the surface of our planet. Economically speaking this ratio between land and sea is a fundamental defect which cannot be changed.

Land is formed into huge blocks which are nearly all in a certain hemisphere. If we were to go into the problem of a complete reconstruction of our planet we should have to envisage a more regular distribution of the land and ocean. Deserts occupy almost fifteen per cent of the earth's surface and these inadmissible losses must be eliminated. A full-scale attack has been launched on the deserts. The day will come in which schoolchildren will take a trip to visit a vestige of the past – a few acres of desert, the only one left on earth as a record.

And what about the subdivision of heat and cold? There are zones which suffer unbearable heat throughout the year. In others, on the contrary, the temperature never rises above zero, not even for a single day. Some 8,000,000 square miles – a whole continent and several islands – are eternally covered with solid glaciers. Posterity has a difficult task in attempting to redistribute heat more equitably.

Mountains are an inconvenience and often uninhabitable. Look on the map and you will see huge regions covered with rugged, inhospitable mountains. The least expert engineer planning the building of our planet would not have placed so many unassailable obstacles on its surface. We will not continue to criticize the construction of our planet because it seems a bit premature, because man's chances of changing the globe are still extremely small, and because he has hardly finished studying his geography and is still very far from having completed his study of biology. Nevertheless, the day will come when the human race will be able not only to elaborate but to realize many plans of transforming our planet on a vast scale.

We know the plan of certain Soviet scientists to build a huge dam across the Bering Strait. Across these narrows a cold current, descending from the Arctic, runs into the warm Pacific. The grey waves of this current carry down icebergs, fog, and cold, exercising an enormous influence on the climate and atmospheric conditions of all the regions of the Far East. This dam will bar the way to the current. Such a construction, even with the limited technical means which we possess today, will not present undue difficulties because the Bering Strait is only fifty miles wide, and the water is only 120 feet deep.

The dam will offer another advantage. As planned, it will not only form a barrier to the cold current but will be able to create a warm current from the Pacific to the icebound Arctic Sea. For this we shall need to instal in the dam hundreds of huge pumps working from atomic power stations built on the spot near the shores of the Strait. The pumps will be able to transfer from the Pacific to the Arctic Sea millions of cubic kilometres of water, creating a current opposed to the one existing today. It will transport from the Tropics to the North Pole a quantity of heat which will be double and perhaps triple that which the oil reserves of the world could provide.

Man will change the climate of Kamchatka, north-east Siberia, and Alaska. He will change the temperature of the Sea of Okhotsk and the vast zone of the Arctic Sea. This rise in temperature will extend over a vast area and will bring immeasurable benefits.

Other no less grandiose plans exist which may eventually be realized. We could build a dam from Newfoundland to Labrador and thus block the cold current which today freezes a vast region of the U.S.A. We could dam the Straits of Gibraltar and exploit the enormous zones of fertile land at the bottom of the Mediterranean. We could divert the warm Kuro-Siwa current into the cold sea of Okhotsk. We could create in the Sahara Desert a freshwater lake which would influence the whole climate of Africa. We could deflect southwards the great Siberian rivers and use their waters to irrigate the deserts of Central Asia. This and many other plans have been worked out.

What is needed to bring them about? First and foremost peace, friendship, mutual understanding among the peoples of the world. We will now record the reflections of scientists who have dedicated their lives to these problems.

CHAPTER 26

Space Travel

FLIGHT through space: this is the most enthralling problem because of the influence it will have on human culture – a problem with which science and technology is confronted and the solution of which is at hand.

It all depends how you define 'solution'. In 1957 the first Sputniks were launched into space. Soon, with more perfected methods, the first exploration of the Moon will take place. Probably by the end of this century men will visit our neighbouring planets. Which of these stages can be considered as the solution of the major problem? There still exist the problems of exploring the more remote planets, the interstellar space which surrounds the solar system, of voyages to the planetary systems of the stars. . . . In these various stages there will never be a definite frontier. Every decade, every century, every aeon, once human activity has been projected beyond the confines of the earth into the Universe, there will always be new discoveries and new victories. Man will never be able to discover the whole Universe, all the stars and the planets, in the way he has discovered all the continents and islands of the earth. Among the captains of the future interstellar space ships, there will be many a Columbus who will say: 'We have discovered a new world.' But there will never be a Magellan to say: 'I have circumnavigated the Universe.' Because the Universe is infinite and infinite are the possibilities of the human intellect to study it.

The branches of science which study space communication are developing at an amazing speed. Each day brings new ideas, the perfecting of former calculations, new data from experiments and observations. It is impossible, in a short chapter, to sum up all the work, all the prognostications and theories. It would need an entire book of perhaps several volumes. Here we intend to give a few of the new ideas, a few aspects of the astronautics of the future as we can imagine them today.

Space travel is no longer a subject reserved for science fiction writers. The problem of interplanetary flights is occupying the minds of engineers, chemists, and biologists. From the pages of fiction the subject has passed to scientific textbooks and the world has already seen how ballistic rockets and the first Sputniks have, to a certain point, solved the problem. We were no longer surprised, therefore, when the scientist Hlebsevitch, the author of a series of interesting plans in the astronautical field, said to us: 'Don't expect any fantastic ideas from me. I shall only speak of the methods of radar control which science possesses today and how it can be exploited for future interplanetary flights.

'Ziolkowski thought that the conquest of space could be carried out by building a giant satellite in which men could live. His idea was that from such a satellite huge interplanetary ships, guided by men and with a crew aboard, could be launched. But scientific advance will enable us to begin interplanetary flight with faster methods. It must be remembered that radio in a mere fifty years has become one of the most important branches of science. It has played a great part in the development of rocket technique. True, we do not yet have rockets in which men can reach Mars or Venus. But the technical means of carrying on a radio conversation between the earth and Mars already exists. If we could manage to instal a modern radar set on Mars we could, by radio, take photographs and televised pictures from that planet.

'By radio we can guide by remote control the flight of rockets and similar machines. Why not use this possibility? Why send manned rockets on a voyage of reconnaissance? The launching of unmanned rockets will avoid the danger of losing human lives, of wasting material, and will speed up the realization of man's dream – the first interplanetary flight.

'Let us return to earth for a moment. You know that the first Soviet Antarctic Expedition of seventy men carried 10,000 tons of food, clothes, and material to build their quarters. How could we build a rocket capable of lifting such a load? In addition it would need a quantity of fuel a thousand times greater than the load. If we were to follow this course and to wait until a manned flight would be possible, then the first interplanetary rockets will be built at the end of this century or at the beginning of the next, as the authors of plans for space exploration believe.

'The launching of a radar-guided rocket is different. So far man has not reached an altitude higher than twenty miles and has never flown at more than 1,500 m.p.h. But what of satellites? In 1957 two Sputniks went into orbit round our planet at an immense altitude and reached a space velocity of five miles per second. Our first dog was carried by a rocket in 1951 to a height of sixty miles. This dog, Ziganok, lives today with Professor Blagonravow. Ziganok blazed the trail for the bitch, Laika, which was carried up to a thousand miles. The instruments on the Sputnik carried out most valuable researches and communicated the results by radio.

'Man has created machines which can solve mathematical problems a million times faster than his brain – machines which can work out production processes far more rapidly and accurately. As a creative thinker man stands very high in Nature, but as a technical executor he has to bow before the machine. This is why it would be quite wrong to send men on the first space explorations.

'In recent years I have been engaged on the technical methods of exploring the Moon, Mars, and Venus by means of rockets capable of transporting and unloading on those planets small laboratory trucks, radar-controlled from earth. We can already try and forecast the approximate date when we shall launch these space ships. We are at present building radar-guided rockets to reach the Moon and the neighbouring planets. In the next few years we shall be able to approach the Moon, Mars, and Venus without waiting for an artificial satellite capable of carrying human occupants. The first guided rockets will soon explore the Moon and in the following five or perhaps ten years there will be a permanent scientific observatory on the Moon. Return flights to the Moon will become a commonplace by the end of the century. At the beginning of the twenty-first century the Moon will become the seventh Continent of our Planet, and, strange though this may sound now, we shall be in a position to exploit its natural wealth. . . .

'In order to undertake a flight to the Moon thousands of tons of fuel are needed. But we are looking for another more economical and more rapid system. We shall first send to the Moon an unmanned rocket carrying a small laboratory car, which will be radar-directed from the earth. The fuel consumption of this flight will be only 250 tons. On the basis of orders received from earth the little laboratory car, travelling over the surface of the Moon, will carry out the instructions and transmit a televised reply to the earth. It will examine the soil, the temperature, and the composition of the space round our satellite. Contact with the earth will be assured. A similar small laboratory car will also be sent to Mars, possibly between 1965 and 1971. To land such a mobile laboratory on Mars will require 6,000 tons of building material and fuel, while to explore Venus (without the small car) we shall need to build a five-staged rocket, each section of which, on launching, will weigh fifty tons.

'Today we are planning on the assumption that neither Mars nor Venus are inhabited. But suppose we find this to be untrue? Then we shall try to build space ships which can enter into radiotelephonic or television contact with the inhabitants of those planets. Only then shall we tackle the most difficult problem of how to land man on them.

'The Moon will become a radio-telescope for the purpose of retransmission. Transmissions from the Moscow television centre, for example, will be received on the Moon, reinforced, and retransmitted back to the earth. These pictures will be seen by the inhabitants of half the terrestrial globe. Telephonic and phototelegraphic contact via the Moon's surface will greatly amplify long-distance communication on earth. Ships at sea or aircraft will be able to intercept the televised transmissions from any country. For long-distance communication they will be able to utilize ultra-short radio waves which at the moment it is not possible to do. On the Moon there will be a radio beacon the signals of which will guide aircraft, ships, and finally space rockets. In this way will be born lunar radio navigation.

'Towards the end of the century men will be able to observe the whole earth as if they were on the Moon and not only on television or on a photograph. A special post for earth observation will be established on the lunar scientific station. An electronic machine coupled to a telescope will photograph the earth's surface. The results will be greater than any we could obtain on earth, for on the Moon there is no atmosphere to blur the picture. Today we cannot obtain a perfect picture enlarged more than 500 times. Many details remain invisible. There exist already, of course, telescopes with an enlarging power of 10,000. If such a telescope were placed on the Moon where there would be no atmospheric hindrance we could see the earth brought to within fifteen miles, as though seen from an aircraft. But from a plane only a relatively small part of the earth's surface is visible, whereas through an electronic telescope we shall be able to see an entire hemisphere and, in the course of twenty-four hours, the entire surface of the globe. An optical paradox: observed from a lunar telescope the earth would appear closer to the Moon than the Moon appears from the earth through a terrestrial telescope. In ten to twenty years we shall be able to obtain perfect weather forecasts for the whole globe from the Moon. With these lunar telescopes we shall be able to see where the clouds build up, their direction and their speed. Such information will be of the greatest value for supersonic aviation, particularly on trans-oceanic flights. Today, the TU 104 flies from Moscow to London in three hours, but in a short time this trip will take only fifty minutes. Thus, before taking off, pilots will want to know the weather conditions in advance over several thousand miles.

'On the subject of atmospheric conditions, the Sputnik will be able to advise us in time of harmful cosmic radiation and the course of meteors which are a danger to interplanetary flight. An interplanetary meteorological signalling system will be born.

'In the twenty-first century man will be in a position to develop his study of the solar system and to discover once and for all the entire mechanism of the planets' orbits. Space radiolocation, today in its infancy, will allow us to trace with the greatest accuracy the coordinates of the nearer planets, to an approximation of some miles, whereas today the margin of error runs into thousands of miles. We can foresee the enormous development which will take place in space television.

'Radar-guided rockets will also set out on journeys to the central star of our planetary system. Equipped with a special television eye, encased in protective metal, they will travel beyond the orbit of Mercury, the planet nearest to the Sun. Scientists will discover the secrets of the gigantic thermonuclear furnace which we call the Sun. At the beginning of the next century they will begin to attack with these rockets the so-called outer planets – Saturn, Jupiter, Uranus, and Pluto. Astronomy will gradually be transformed into a vast branch of applied science and will develop in many directions. Specialists will devote their attention to individual planets. Today we study the geology of the earth, its meteorology, and the physics of its oceans. The next generation of scientists will be lucky enough to study the geology and meteorology of the Moon, Mars, and Venus, and the physics of the seas on Venus.

'Rocketry will develop in two directions. We shall try to solve more complicated problems by rockets and yet simplify the methods of their control. Some people may think that rockets will fly on their own to other planets without the participation of man, that they will become autonomous, and that our only task will be to guide them from the earth. If this were the case, out of 10,000 rockets sent from the earth to other planets, as the result of inevitable errors in calculation many of them would never arrive at their destination. We should suffer enormous loss of material; but what is the alternative solution?

'Above all we must have a reliable radio link with the rocket so that we can correct its flight. The apparatus for this purpose will increase the weight of the rocket, but as a reward our space explorers will be assured of reaching their goal.

'Let us try and visualize the radar stations on earth. They will be placed in every continent, and the cost of each will be no more than that of a big industrial plant. They will be equipped with many automatic machines, computers, television and retransmission sets, a series of huge mirrors, and aerials 100 yards apart.

'Thousands of rays like invisible threads will connect the rockets in flight to the station. Many of them will travel for years and years towards far distant planets. The various stations will be in constant contact with them. They will hand on the rocket from one station to another so that it never strays outside the radiovisual field. Through these many space windows, specialists in the most disparate branches of science will be able to receive a host of valuable information. By cable and radio-relays the televised pictures of the Sun and the planets, all the measurement data, will be transmitted to the Institutes of Biology, Geology, and Meteorology. The radio signals, the pictures of the planets, will be recorded on a magnetic ribbon and preserved in the records. Later automatic computers will deal with all this data.

'To guide the rockets and to receive information from them will be a task for thousands of specialists. Given the development of radar, thousands of scientists will be employed in the new field of cosmic space. There will be no intervals between a geophysical and any other year. The twenty-first century will become the first international geophysical century.

'All I have said, all my forecasts can only be realized provided the peoples of the world remain at peace. The combined forces of science and the human brain must be utilized not for an armaments race but for the solution of these grandiose problems, the only problems worthy of man. If the endeavour and money spent on missiles with war-heads were used in preparation for interplanetary flight our forecasts would be proved true very much sooner.'

CHAPTER 27

The Unexplored Regions of the Earth

'YOU will certainly think that geography and geology by their very nature are sciences which could not develop to infinity, because the object of their researches is limited to our planet. This is true to a certain extent. But we can guarantee that not only in the twenty-first century, but very far into the future, both these sciences will develop enormously.'

We were in the modest but comfortable study of Dmitri Ivanovitch Scherbakov at the Soviet Academy of Science. On one wall hung a geological map of the Soviet Union. On his writing table we saw a fragment of dark-green mineral weighing about six pounds used as a paper weight to hold down a pile of foreign magazines.

The professor looked up with a smile. He has seen a great many things in his life and his hair is grey. He has seen the Aurora Borealis, explored the ice floes of the Arctic Circle, and his face has been lashed by the winds of Tibet. This man of about sixty has explored the Khibini mountains, as well as the deserts of Central Asia, Kamchatka, and the Carpathians. His travels have in fact taken him all over the world. No one is in a better position than Scherbakov to know the prospects of geographical and geological development.

'Many people think that there are no parts of the earth left where man has not yet set foot. But this is far from the truth. In Africa and South America, not to mention the Antarctic, many regions still remain unexplored. A few years ago an airman, Jim Angel, discovered in the Venezuelan Savannah a waterfall far larger than the Niagara. No geographer has yet set foot on the banks of this waterfall and the geologist's axe has not yet buried itself in the neighbouring rocks.

'There are a host of similar examples. In recent years, actually in 1954, Australian airmen discovered regions in New Guinea populated by tribes which had no contact with any of their neighbours. These savage tribes were estimated to be about 100,000 strong, but no anthropologist has yet entered their huts and no philologist has been able to study their language.

'The discovery of diamond deposits in our country is the most important geological find in recent years. The era of the great geographical and geological discoveries is by no means over.

'But this is not the point. Let us assume that no single unexplored portion of the earth remains. Even then, a knowledge of the land mass is not everything because, as a whole, it forms only thirty per cent of the surface of the globe, while the rest is covered with tidal waters. Beneath the sea are great mountain ranges, such as the Lomonosoff Range. Knowing only a third of the surface area of our planet, we are not in a position to establish the general laws of its structure. The mapping and charting of the ocean bottom will be one of the gigantic tasks confronting scientists of the twenty-first century. This will not be of purely theoretical interest. Today we have succeeded in penetrating the bed of the Caspian Sea. There is no doubt that mining below the ocean bed and in the shallower seas will start in the near future. The first boring operations will probably take place in the Persian Gulf and the Red Sea. Then we shall continue in deeper waters and we shall certainly manage to extract minerals from depths of 6–10,000 feet. Man, the lord of Nature, will exploit all the riches of our planet wherever they are to be found.

'Even greater prospects await the geologists, who cannot possibly rest on their present knowledge, which is limited to the soft strata of the earth's crust. Today we have only bored down to 21,000 feet, which is like exploring the inside of an apple and stopping at the rind. Sound waves are the only element which can provide information on the depths of the earth. So far we do not know whether the centre of our planet has a fiery stellar temperature or a relatively low temperature of 1–2,000° C., or whether on the contrary it is cold. In the twenty-first century it will be possible to bore down to 100,000 feet through the earth's crust, and this will certainly give us a better knowledge of its core. Geologists will be able to descend more deeply into the bowels of the earth and to examine them with direct and efficient methods.

'In this connexion I wish to discuss a force which today is little used but which in the future will be greatly exploited – the heat which comes from the centre of the earth. The electric power station of Lardarello in Italy, the thermic establishment in Reykjavik, a few factories in Japan, in the U.S.A., and in our own Kamchatka are today all consumers of mineral heat. But this great source of energy is universal. The volcanoes, geysers, and hot springs are only small fissures through which this heat leaks.

'In the near future we shall certainly have to build electric geothermic stations in places where the heat is nearest the earth's surface, in regions where steam and hot water are ejected naturally from the active volcanoes and geysers – in Kamchatka and certain regions in the Caucasus and in Central Asia. But it is merely a question of descending deep enough and the heat can be found anywhere. One of these geothermic stations could quite well be built in the neighbourhood of Moscow.

'Let us visit in our imagination this marvellous power station. A grey-blue building stands among the birches. It is not served by rail, which was essential for the thermo-electric power stations in the middle of the twentieth century. No white walls of a dam in the neighbourhood, no hydro-electric station reservoir. Only a few boring towers driven by high-frequency current and a system of tubular drills covered with thick insulating varnish. This is all we can see in the vicinity of this building.

'The high-frequency geothermic station draws its power from the bowels of the earth. At a depth of between 45 and 60,000 feet the drills descend until they come to the magma compressed by the vast pressure of the upper strata. During the crystallization of the magma great quantities of incandescent gas and steam are released which have an outlet through a tube as though it were being ejected by a volcano. But this modern volcano is subject to the will of man. The mass of steam and gas it ejects is conveyed by tubes into separators, where the valuable elements are condensed and purified, harmful agents and steam being eliminated. In this way our geothermic station collects helium, hydrogen, magnesium, aluminium, calcium, sulphur, and many other substances for the needs of our economy.'

We went round the various departments. In one of these, chemical elements and their compounds, compressed and solidified in giant condensers, heated the semi-conductor batteries which generate the electric current.

From an adjacent department we could hear the regular throbbing of machinery. Steam and gas turbines drove the generators. This was very characteristic of power at the beginning of the twenty-first century, as the automatic electro-generators of the thermic power stations will not yet have been entirely replaced by semi-conductor thermic elements.

The professor stopped and placed his hand on a block of stone which had caught our attention at the beginning of our conversation. 'This is another commonly found mineral which has a brilliant future: basalt.

'Basalt is dark green, black, chestnut, or grey in colour. It can be dense or porous and is volcanic in origin. Whole mountain ranges are formed from it. Fiery rivers of basalt pour from the volcanoes of Hawaii, Kamchatka, etc. All over the world, if we penetrate the upper strata, we can find seams of basalt. It contains twenty to twenty-five per cent iron, about the same proportion of magnesium, a little less calcium, three to five per cent of potassium hydroxide and sodium, and a small quantity of aluminium, in addition to minute quantities of other elements, including rare and precious metals. It is not profitable to extract iron from basalt because today we possess minerals which are far richer in this metal. It is not even profitable to extract magnesium or calcium separately from basalt. But it will be possible to obtain a combined product of all the elements of basalt, eliminating the dross.

'The minerals richest in iron and other metals are almost completely exhausted, or will be within a few years. But all over the earth basalt, the mineral of the future, is to be found in unlimited quantities. The metallurgists of the future will also be able to utilize a whole series of other minerals not used today or used only for one of their component elements.

'Let us consider geography as a science. I believe that in the near future its character will change. From a purely descriptive science such as it is today it will become an applied science. In the history of nearly all branches of science two periods can be distinguished. The first is the period of collection of data and the discovery of certain laws of Nature, the second when science begins to apply these laws. The geographer of the future will be preoccupied in actively changing the structure of individual places and perhaps of entire continents. At present the study of the influence of warm ocean currents allows him to predict climatic changes if they are diverted from their course. In all probability the geographer of the future will be able to divert not only the course of marine currents but also the course of the winds. Then a moist climate will be created over the deserts and the wastes will flourish. The perpetual cold and damp of Siberia, North America, and Greenland will be eliminated. The torrid climate reigning in some regions will be rendered milder. The geographer will become the creator of Nature.'

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A soft feminine voice announced on the loudspeaker: 'Passengers for Sakhalin on the Moscow plane can use trains, cutters, or helicopters to reach various points on the island.'

It was a bright July morning in the summer of 2007. Not a breath of wind, so we decided to take the cutter to visit the famous Sakhalin dam. When our small craft put to sea we began to recall all we knew of this strange construction, unique in the world.

The idea of joining Sakhalin to the continent had long been under consideration. A plan was drawn up in the middle of the nineteenth century by Gennadii Ivanovitch Nevelsky, who discovered this strait in the 1850s. The strait was named after him and it was finally proved that Sakhalin was not a peninsula but an island. Nevelsky proposed to build a railway embankment across the Tartar Strait. But how was this to be used in winter when the strait was frozen? It was next proposed to dig a tunnel, but this would have been too costly.

In 1951, the engineer Nikolai Georgievich Romanov visited the island with a large expedition. He was struck by the ideal natural conditions of the place. To the north the island is bathed by the cold Sea of Okhotsk and to the south by the warm Yellow Sea. The northern side of the island is exceptionally cold, and along the shores extends a tundra or marshy swamp with stunted trees. To the south of the island the climate is warmer and richer in vegetation, resulting in better living conditions. The warm Kuro-Siwa current, which flows to Sakhalin from the south, does not cross the Tartar Strait but turns off into the Pacific, depriving the island of its life-giving warmth.

Would it be possible to change the course of this current, forcing it to enter the Tartar Strait and thus warming not only the northern part of the island but also the shores of the Sea of Okhotsk and changing the coastal climate of the Far East? The solution of this problem is far more important than building a ferry or a tunnel from Sakhalin to the mainland.

In order to divert the current from the Yellow Sea into the Sea of Okhotsk across the Tartar Strait, the Soviet scientist, P. J. Koloskov, proposed in 1931 dividing the waters of the Amur into two streams and directing one of these towards the southern zone of the strait. In this way the warm waters of the Amur would be driven from south to north across the strait and finally into the Sea of Okhotsk. It was a very ingenious plan, but it was not certain that the warm current would take the desired course.

Romanov, the engineer, stood on the shore of the strait watching the swirling waves, the tides, and the vast masses of water flowing northwards. He was suddenly struck with a brilliant idea which later developed into a feasible plan, from the engineering point of view, to be carried out in 1977. . . .

We entered the narrowest part of the Tartar Strait, which is called Nevelsky. Here the distance between the island and the mainland is nearly three miles. We saw a low dam uniting the two shores from Cape Lazarev, on the mainland, to Cape Pogibi, on the island. With the naked eye we could see a train and a few cars. With the strait barred in this way by the dam how could ships pass? The pilot of our cutter, an old salt, looked at his radar screen and said:

'The water in this channel is not very deep, only two fathoms, but in some places it is as much as three. In the middle of the strait in the approach channel the depth is five to seven fathoms. Previously, the strait was only opened to shipping in summer, but now it is open all the year. Have a look through these glasses . . .'

The dam rose about six feet above the water line.

'At this spot,' explained the pilot, 'the water never reaches the top of the dam.'

The high tide was imminent. Through our binoculars we could see clearly that in the centre of the three-mile-long dam a steel lock gate 300 feet wide was beginning to open. This gate was erected on pontoons and served as a drawbridge. Even large vessels could now pass through. To right and left of the main lock smaller gates opened. Our cutter had almost reached the embankment. 'Stop engines,' ordered the pilot, and then turning to us he added: 'now we will follow the stream and it will carry us where you will be able to see . . .'

The current of the high tide took possession of our little craft and drove it rapidly towards the lock gate. The helmsman merely kept on his course. None of us were sailors but we realized that the current was running from three to four yards per second.

'In twenty-four hours,' said the pilot, 'there are two high tides. Every six hours, at the turn, the water of the strait flows in the opposite direction. Through the gate in a northerly direction three cubic kilometres of water pass in twenty-four hours – four times more than the Volga, Don, and Dnieper flow combined. Even more than the Amur in spate. Before the dam was built this warm water flowed back with the low tide. The water went to and fro in the strait. Now, at the beginning of the ebb tide, this lock closes automatically. The warm water remains on the other side of the dyke and is directed into the Sea of Okhotsk. The Sakhalin dam is a valve through which the warm water passes in only one direction, towards the north. It is like a gigantic pump which empties the Yellow Sea into the Sea of Okhotsk. It works by the power of the sun and the moon which cause the ebb and flow of the water by their attraction.

'This pump has been working for thirty years,' said the pilot. 'I remember when they started to build it in 1970. It required three million cubic metres of stone and earth and one million cubic metres of cement. But to build this twenty-metre-wide dam cost only a third of what a tunnel under the strait would have cost. What marvels this Sakhalin dam has accomplished, you will never be able to credit.

'Until 1970 people crossed the Nevelsky Strait in winter on foot. The ice was three feet thick. In those days ships from Vladivostok to the Sea of Okhotsk had to make a long detour, turn south, and then put about and coast along the whole of Japan. Now we have our own interior route.

'I remember that on the navigation charts there was a red line, the January isotherm. There, began the ice at 10° below zero. This was the "front line" which barred access to the transpolar region. We used to call it "isotherm minus 10". It stretched to the bridge of Lasariew, rounded Sakhalin, joining the shores of the Sea of Okhotsk on the other side. Now it does not reach Sakhalin. It has been transposed perhaps to Anadyr or to Chukotsk.

'In the last thirty years the average annual temperature on the shores of the Sea of Okhotsk has risen by 10°. Now it is rare to find ice in these waters. The geographers are flabbergasted,' the pilot said with a laugh. 'They have lost the cold and in a few years' time not even an expedition will be able to find the coldest point in Eastern Siberia. The cold is retreating ever farther north. In a few years the pump would empty the whole of the Yellow Sea and dry it up were it not continually refilled with the warm waters coming from the south.'

We were approaching the great harbour of Sakhalin. Many tankers flying the flags of Indonesia, Vietnam, Japan, and other countries were waiting near the lock entrance.

'Tell us, chief, haven't the Japanese lost a lot by this transformation of the Kuro Siwa?'

'Good heavens, no! On the contrary, recently when we celebrated the thirtieth anniversary of the Sakhalin dam some Japanese fishermen, who live in the Northern Nippon Islands, came to visit us. The only people who are upset are those that love skiing. There has been no snow on their islands for fifteen years! The climate has improved and become more constant.'

The pilot went to the rail and in the traditional manner, which has been preserved, cried to his non-existent crew: 'Moorings away!'

CHAPTER 28

In the Lunar City

'IN the first quarter of the present century lived a very talented poet, Valery Brusov. He had a great knowledge of man's past, but was far more preoccupied with the future. He looked forward to the time when a single city would cover the earth "gleaming like a mirror". In one of his plays he describes the sunset of life on earth which had grown old, with a single city of glass beyond which there was no trace of breathable air. But Brusov was wrong.

'The future of the human race will not be an inglorious death in a greenhouse or a glass container. The human race, cautiously at the outset, will explore the limits of the atmosphere and will then conquer the space around the sun. This is Ziolkowski's prophecy. Not only on the earth but on the other planets and satellites will rise cities of glass with artificial atmospheres, with gigantic greenhouses, helio-electric stations, and everything necessary for a completely basic change in living organisms.'

The speaker, the President of the Astronautical Institute, Nicolas Alexandrovitch Varvarov, paused.

'The first city of this type will be built on the moon. Look at these pictures taken by our Sputnik. All these circles and craters appear admirably suited to the foundation of cities covered with colossal glass roofs. The attack on space began with the launching of the Russian Sputniks. The next stage will be the attack on the moon by sending small laboratory-cars and ultimately teams of scientists and technicians. Then we shall have the problem of creating on the moon a permanent populated centre, a base and a departure station for space ships which will leave the earth and land there, on the way to other planets. At the beginning, of course, our moon settlers will be supplied with all their needs from the earth, but this will be a costly business. A slice of bread despatched from the earth to the moon would cost its weight in gold. Thus one of the first problems to be tackled will be to make the moon self-supporting for its new inhabitants. This problem will be solved by the end of the century if . . .

'This if . . . is provided peace reigns on earth. The Soviet astronauts, in common with the astronauts of the whole world, are deeply interested in maintaining a lasting peace among the peoples of the world. Future space flights will be possible only if the earth does not become involved in an infernal atomic war. Personally I believe that the various powers will remain at peace and that is why I have the honour to invite you to take a trip round the first lunar city which will be built in the Eratosphenes crater.'

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And here we are on the moon!

The specially built car took us along a smooth road through pinnacles of volcanic rock between the cosmodrome and the city. It was a broad road upon which the rain never fell but which was covered with dust. On the moon there is neither rain, wind, nor atmosphere. The car was hermetically sealed and air conditioned, otherwise we should have been roasted in this metal envelope by direct solar radiation.

We entered a narrow gallery hewn out of the rock and ahead of us loomed an aluminium door. This was an air cataract. In the city we were about to enter, the atmospheric pressure barely registers 500 millimetres on the barometer – in other words, a third less than pressure on earth at sea level. But as it contains more oxygen than the atmosphere of the earth it is possible to breathe without endangering health. So that the air should not leak through the glass roof of the city, all the exits are kept closed and entrances and exits are made through the cataracts of air.

The second aluminium door opened and we entered the city. Now we got out of the car and breathed the artificial atmosphere of the lunar city.

Above us was a transparent dome built in several layers, some of glass, others of plastic. The composition of the gases enclosed between the transparent ceilings also varied. This elastic glass roof replaces the earth's heavy atmosphere. It has various functions – to allow entrance to the city of only that proportion of solar rays which arrive on the earth's surface; to capture and transform into electric energy that proportion of solar radiation which is caught by the earth's atmosphere; to serve as a protection against possible falling meteorites.

The roof itself is supported by a few aluminium pillars interspersed with strips of glass and plastic. The columns do not actually support the roof. On the contrary, they anchor it, avoiding the possibility of it being torn away by the pressure of air.

We passed a few flowering shrubs and fruit trees. They were not easy to recognize although they were all plants to be found on earth, since in lunar conditions a normal radish, for example, will grow to the size of a date palm and an onion will have a stalk thirty feet long.

We noticed a glass wall with a double door. Similar walls were placed every 800 or 1,000 yards. Their function was similar to that of watertight compartments in a liner. In case of collision the water immediately floods the compartment and the ship is saved. On the same principle, if a large meteorite penetrates the roof of the lunar city the damage will be restricted to a certain zone.

Aluminium, glass, plastic material, water, and soil! But how could all this have possibly been brought up from our planet?

The aluminium was mined on the moon, the glass and the plastic material were made in lunar factories. The water comes from the depths of the satellite and gives the necessary humidity for cultivation of the soil. Oxygen and nitrogen are obtained from lunar minerals. The lamps which burn during the long night, which lasts almost a month, are fed from batteries which, at the same time heat the city and supply the power for the factories. All this has been set in motion and the whole work is designed to utilize the energy of local and solar atomic power stations.

The lunar city is not only self-supporting but is also working, one might say, for export. For example, synthetic fuel for rocket servicing is prepared for rockets departing to the earth; plans are ready for the construction here of a wharf for cosmic ships. Soon rockets, built in lunar factories, will depart on long-distance journeys. The lunar cosmodrome will soon see the launching of an enormous rocket bound for Mercury, having on board the first expedition of earth's scientists.

CHAPTER 29

Through Interstellar Space

LET us speak once more of the dreams of the twenty-first century scientists. . . .

Professor Kiril Petrovich Stanyukovitch ran his hand through his hair. He has the reputation of being a keen scientist but forbidding and rather pedantic.

'Incidentally, as you yourself realize,' he began, 'for the scientists of the twenty-first century to be able to dream of the future it is necessary that the twenty-first century arrives. If the forces of evil are allowed to unleash an atomic war, if the hydrogen bomb explosions spread like venomous fungi covering continents and oceans with the fatal ashes of the isotopes, and poison the earth's atmosphere, the twenty-first century will never arrive. Today, for the first time in history, man has the means to destroy all life on our planet. I take this occasion to associate my voice with the voices of so many who demand the immediate cessation of all nuclear tests, and that nuclear energy be abandoned as a method of warfare. But I do not think that the human race wishes to commit suicide. The twenty-first century will arrive and what a magnificent century it will be.

'You know that in the last few years scientists have discovered the existence of the so-called anti-particle, a kind of matter in reverse. We have been able to obtain some artificially. In present-day conditions these anti-particles do not live long. Hardly have they been born than they disappear, within a fraction of a second. They cancel out as soon as they meet with the complementary particle. From this encounter an enormous amount of energy is released, a hundred times greater than that which can be obtained by nuclear reaction.

'It is possible to imagine atoms and their molecules formed entirely of anti-particles. It is possible that in the remotest quarters of the Universe there exist entire galaxies of anti-substance. The scientists on the planets of these galaxies may perhaps have obtained for the first time the elementary particles of our world and are examining them with the same sense of wonder as we are examining these anti-particles.

'Let us take an extravagant case. A being from this anti-world reaches the earth. He could only survive in a "power-dome", a sphere which separated him from our substance. And now he falls in love with a girl from our world. This could bring about a cosmic tragedy because their first kiss would produce a colossal explosion due to the contact of substance with anti-substance.

'Today I am engaged in the study of gas dynamics. I am interested in the problem of the movement of particles of matter in a hypothetical explosion of this type. To understand this extraordinary interlacing of gaseous and light waves with the poles of magnetic fields and of gravity, in the chaos of inter-nuclear forces, is an extraordinarily interesting and complicated problem. But even today it is possible to envisage a peaceful course of this transformation process of the particles of matter and anti-matter into light rays, into quanta or photons of electromagnetic fields.

'This peaceful evolution will be possible if we feed matter and anti-matter into a combustion chamber in the form of very rarefied gas, in small quantities and in very small jets. Scientists will possibly be in a position – by surrounding the reagent substances with invisible walls of electromagnetic fields – to control the results of this reaction (the photon stream) in a single direction. Then they will be able to create the most powerful motor theoretically conceivable, the photon rocket. I believe that towards the end of the century the theoretical studies needed to put this idea into practice will be complete. A rocket equipped with this motor could produce fantastic experiences almost inconceivable today, above all in interplanetary flight.

'Fifty years have passed since science entered a completely new phase of development: the theory preceded practice and pointed the way. The steam engine was built only as the result of a theory. The latest aircraft engine, the jet, was first planned with mathematical formulae and then built. Today it is practically impossible to make a serious discovery or a new invention without their being preceded by long theoretical work. The scientists of the 1950s have already calculated in theory the construction of interplanetary ships, the trajectory of their flight, the possibility of contact and of supplying the astronauts. But the actual flight has not yet been realized. Our colleagues of the next century will first have to make theoretical calculations before they can put their plans into practice. Their problems will be infinitely more complicated and grandiose in application than interplanetary flights. To put you in the picture I will give you a few figures. As you know, Proxima is the nearest star to our solar system. If we wish to represent to scale the reciprocal location of our solar system and that of Proxima we should have to take a piece of paper fifteen miles long. In one corner we should put the whole of our solar system represented by a circle less than five millimetres in diameter. We could not indicate the Sun, whose diameter would be in proportion less than a micron – in other words, the thousandth part of a millimetre. At the other end of the sheet, fifteen miles away, we should place an almost invisible dot to represent the star Proxima.

'Probably as a base for one interstellar ship we should use one of the satellites, Saturn or Jupiter, or perhaps one of the larger asteroids. In the space ship the combustion chambers and the nozzle of the motor will not resemble the elements of a motor of our day. They will probably be rings of magnetic fields. The reactor, or to be more precise the reactive ray, launched from the space ship will be so intense that even millions of miles away it would burn up all living things should it fall on earth. It is for this reason that the cosmodrome will be situated so very far from the earth.

'The flight of a photon rocket will be followed from the earth on very complicated instruments. We do not know yet how we shall be able to keep in touch with the rocket because its speed will be very close to the maximum speed in Nature – in other words, the speed of light in a vacuum and of radio waves: between 125,000 and 190,000 m.p.s. Our space ship will consume ninety per cent of its initial mass – in other words, the first stage of the rocket. When the motor is exhausted contact from the earth with the interstellar traveller will probably be impossible. Ten or fifteen years will pass and once more, in the black abyss of space, will be born a luminous star which will rush towards us at a fantastic speed – a star which will shine from its power ray like the beam of a searchlight. The astronauts will switch on the photon motor. A few swift manoeuvres and the ship will go into one of its possible orbits and will once more become a member of our solar system.

'I do not believe that the next century will see the realization of this flight. But the scientist of that century will calculate the interstellar trajectory, will make more accurate plans, and will subject to mathematical analysis all the details of this plan, which today is almost inconceivable. Just as we today dream of the first flight to the moon, once they have reached all the planets of the solar system they will dream of this excursion into interstellar space.

'What are the prospects of a journey to the farthest stars? Today we can only say that a return journey to stars which are only nine or ten light years away would take not more than twenty-five years. It would not be rational to embark passengers who would never return to earth but have to spend all their life on the journey. Nevertheless, new possibilities of the greatest interest have been opened up by Einstein's theory of relativity.

'Given that the velocity of the space ship is equal to the speed of light, the course of time on it would be much slower than on earth. On the basis of the measurement of time on earth a hundred years could elapse. In this time the space ship would travel a distance (according to terrestrial measurement) corresponding to a hundred light years. But in reality, aboard the space ship only two or three years would elapse and the men on board would only age to this extent. They would visit planets and stars at a great distance from our sun and the return journey to the earth, according to their time, would be in two or three years. Nevertheless, on their return to earth the astronauts would not find a single person they knew still alive. Because on earth, during the same period, two hundred years would have elapsed.

'Perhaps astronauts of the Universe, men who at their vertiginous speed will almost abolish time, will be able to explore and study the remotest parts of our galaxy and perhaps visit other galaxies.

'Not so long ago the conclusions of Einstein's relativity theory appeared strange, paradoxical, and almost theoretical. Today the physicist cannot overlook the exact laws of this brilliant theory. The time will come, however, when these laws will have to be known by all the pilots of space ships. But again, these are problems which the scientists and engineers of the twenty-first century can only dream of solving.'

And this brings to an end our reportage of the twenty-first century.

We must apologize to the reader for the incompleteness of the individual chapters, for some repetitions and perhaps for eventual contradictions in our text.

But it must be remembered that in this book we have voiced the opinions of many people, and that each of these people thinks in his own way and imagines the future of science and technology according to his own ideas. For example, the figures for the output of electric power in Russia in the year 2007 conflict. The forecasts of motor-car models in the same year also differ. If we already knew its structure, what would the engineers and designers have to discuss in the next fifty years? The contradictions are of no great importance. The reader can sum up the pros and cons, accept this or that opinion, and may perhaps want to collaborate in solving some problem. The only aim of this book is to put the reader on that path.

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